FINAL REPORT

20010382

A GROWING HIGHER-VALUE CROPS WITH IRRIGATION

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Final Report

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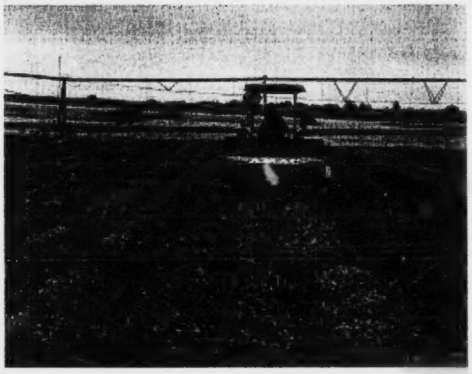
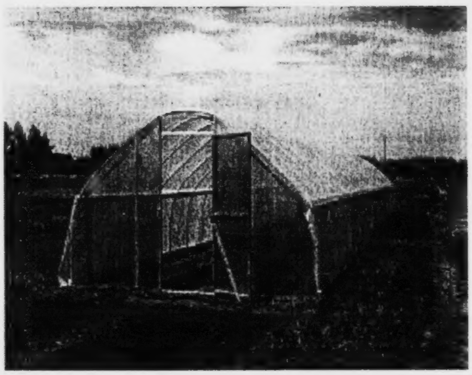
GROWING HIGHER-VALUE CROPS





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Executive Summary

The Canada-Saskatchewan Irrigation Diversification Centre's (CSIDC) mandate is to conduct applied research and tech-transfer activities to enhance crop diversification and value-added opportunities under irrigation. This includes identifying higher-value cropping opportunities with value adding potential, and developing cost-effective and sustainable agronomic practices for irrigated production. The project was designed to develop/refine management practices for a wide range of crops and production practices with economic potential. This includes (i) harvest management for seed potato, (ii) Season extension technology for warm-season vegetables, (iii) storage management for cabbage, and (iv) Irrigation scheduling for pumpkin and (v) agronomic practices for commercial scale production of St. John's wort.

Harvest Management for Seed Potato

The concept 'Northern Vigour' in seed potato has resulted in considerable expansion of the seed potato industry in Saskatchewan. Commercial potato growers demand vigorous, disease-free tubers of specific size grades. As such, the seed crop should be raised appropriately, top-killed and harvested at a suitable time to produce high quality seed-tubers of the required size grade as demanded by the buyers. This project was designed to develop suitable harvest management practices to produce high quality (uniform size grade with high productive capacity and) seed potato in Saskatchewan. This study examined the effects of harvest management practices, i.e. flailing or chemical desiccation, and desiccation timing, on physiological condition of seed potato and productivity of seed lots for commercially important potato cultivars such as Atlantic, Russet Burbank, Russet Norkotah, Dark Red Norland, Ranger Russet, and Shepody. Comparisons were made under both irrigated and dryland production in order to provide information to both irrigated and dryland producers in Saskatchewan. This study consisted of two components: (i) determine the effects of top-kill method, top-kill timing, and seed growing condition on seed grade tuber yield and (ii) the effects of top-kill method (flailing, flailing + desiccation) and timing (early and late), seed-tuber grade (Grade A and Grade B) and seed growing condition (dryland and irrigation) on productivity of progeny.

Top-kill Method and Timing on Seed Grade Yield:

- Irrigated production produced higher seed-grade yields than dryland production.
- Delaying top-kill produced higher yields.
- Potatoes top-killed by flailing or by chemical desiccation produced similar seed grade yields.
- Dark Red Norland was generally the top yielder.
- Under dryland, yield rankings of the various cultivars were somewhat similar across the different top-kill dates. But under irrigation, the cultivar yield rankings were variable among the various top-kill dates.

Effects of Seed Production Agronomy on Productivity of Progeny:

- Seed crops top-killed by flailing or chemical desiccation produced similar yields.
- Productivity of seed crops raised under dryland and irrigation were similar in 2003 and 2004. However in 2005, seed crops, except for Dark red Norland, raised under irrigation produced higher consumption grade yields than the seed crop raised on dryland.
- Top-kill dates of the seed crop generally had no effect on the productivity of the progeny.
- Generally, Grade-A seed produced higher or similar consumption grade yields than Grade-B seed.

Season Extension

Season extension techniques for the production of warm season vegetable crops are becoming more popular in Saskatchewan. In 2004, the Canada-Saskatchewan Irrigation Diversification Centre conducted studies aimed at maximizing production and economic return for cantaloupe and pepper utilizing "High Tunnel" season extension technique.

Agronomic demonstrations included a green pepper plant population study and cantaloupe plant population and planting material (transplant vs. direct seeding) studies. The green pepper study compared 15cm, 30cm, and 60cm in-row spacings at a 30cm between row spacing. The cantaloupe study compared 30cm and 60cm in-row spacings at a 60cm between-row spacing using both direct seeding and transplants. Irrigation was supplied with trickle tape.

- Pepper yields increased with closer in-row spacings.
- Total yields were similar during 2003 and 2004.
- Only 40% of the peppers matured to red color in 2004 as compared to close to 80% in 2003.
- Gross returns in 2003 were $41/m double row, $33/m double row, and $23/m double row for the 15cm, 30cm, and 60cm in-row spacings respectively. Returns were $34/m double row, $28/m double row, and $23/m double row respectively in 2004.

- Cantaloupe yields were variable between years.
- Early planting produced higher fruit yield and yields declined sharply with later planting.
- Plant spacing had no effect on fruit yield.

Cabbage and Celery Storage

In 2005, CSIDC completed a cabbage storage demonstration and an observational celery storage demonstration. Three cultivars of cabbage (Cecile, Bravo, and Lennox) grown under irrigation were evaluated under three separate types of storages (Filacel Cooler-FC, Evaporative Cooler with an humidifier-EC, and Insulated storage with no artificial cooling-NAC).

Cabbage Storage:

The varieties of cabbage used in this study were industry standards. The crop was harvested at maturity. Storage evaluation was done at 60, 120, and 180 days after storage.

- Average cabbage yields were 79 t/ha, 78 t/ha, and 71 t/ha for Lennox, Bravo, and Cecile respectively.
- Storage losses varied between varieties, type of cooler, and the year.
- Lennox (winter storage cabbage) stored better than Cecile or Bravo under all storage conditions.
- Lennox, which is more suited to storage, stored very well in both the FC and EC coolers and reasonably well in the NAC.
- Bravo and Cecile stored well in 2002 but not in 2003 or 2004.
- After 120 days, there was 100% storage loss of Bravo and Cecile in all cooler types.
- Filacel or Evaporative coolers recorded similar storage losses throughout the storage period.
- Cecile and Bravo stored with no artificial cooling or humidification deteriorated very rapidly compared to Lennox.

Economics of Storage (Lennox cabbage):

- The estimated capital investments for a 4 ha (10 ac) operation and facility are $385,000 for the NAC; $415,000 for the EC; and $455,000 for the filacel.
- Gross return for the filacel and EC storages are slightly higher than the NAC due to the

increased prices received during the winter months. However, with the added operating and capital costs for the refrigeration equipment, the net returns are slightly lower than the NAC.

Celery Storage:

- The celery when stored in Filacel remained marketable for approximately three to four weeks after harvest, greatly extending the marketing period.

Pumpkin Irrigation Scheduling

Pumpkin irrigation scheduling demonstration trial was conducted at the Canada-Saskatchewan Irrigation Diversification Centre over a four year period 2002-2005 to determine the total water use and water use efficiency for pumpkin grown in a double row configuration using trickle irrigation and plastic mulch under Saskatchewan growing conditions.

Irrigation treatments consisted of irrigation initiation at a soil available water (A.W.) content of 85% A.W. (Water Treatment 1) and 70% A.W. (Water Treatment 2) and a dryland comparison. Irrigations were scheduled based on soil available water in the top 30 cm of the profile utilizing tensiometers. Soil moisture monitoring was conducted using a neutron moisture meter at varying intervals throughout the growing season.

- The warmer and dryer conditions in 2002 and 2003 resulted in high potential ET and were conducive to irrigated pumpkin production than the cooler and wetter conditions in 2004 or 2005.
- Total water use for the growing season increased as the quantity of irrigation water applied increased, e.g. Water Treatment 1 > Water Treatment 2 > Dryland Treatment
- Water use was highest when conditions were warmer and drier. This resulted in high potential ET increased demand for irrigation.
- Yield response of the pumpkin to irrigation applications appeared to be related to growing season.
- When growing conditions were generally warmer and drier than average, pumpkin yield increased as the quantity of water applied was increased. Yield differences were due to pumpkin size but not the number of pumpkins produced.
- Under cooler and wetter growing conditions, there was no yield response to the irrigation.
- The cool wet growing conditions delayed fruit maturity and favoured disease development.
- There was a significant positive relationship between pumpkin yield and water use when growing conditions were warmer and drier than average.
- Under cooler and wetter growing conditions, with minimal demand for irrigation, there was no significant response of yield to total water use over the growing season.
- When growing conditions favored a yield response to irrigation applications, water use efficiency (kg pumpkin produced/mm water use) decreased as the quantity of water applied was increased. By contrast, when the demand for water was a low, water use efficiency showed little response to water application treatments.
- Adequate heat and moisture are required for optimum pumpkin production. Without adequate heat there will be no response to irrigation water applications.

Develop Cost-Effective Agronomic Practices for Large Scale Production of Economically Important Herbs in Saskatchewan: St. John's Wort

Increasing health care costs, and individuals taking more responsibility for their own health, has lead consumers to seek alternate approaches to treat and prevent diseases. Consequently, natural products (nutraceuticals, functional foods, and dermaceuticals) represent one of the most rapidly expanding industries in the developed countries. To meet the demand of this growing industry, the medicinal and aromatic plant production and processing sectors are growing fast in Saskatchewan. Effective agronomic practices are essential to consistently produce superior yields of high quality herbs. Agronomic research for commercially important herbs were carried out at the Canada-Saskatchewan Irrigation Diversification Centre in Outlook.

Some of the observations from early research with St. John's Wort showed highly variable herb yields, considerable winter-kill under dryland compared to irrigated production. Effective agronomic practices are essential to consistently produce superior yields of high quality herbs.

St. John's Wort is a perennial. Flowering tops are harvested for commercial use as the flowers and leaves are found to contain higher levels of hypericin. Plant growth characteristics and harvest height can affect yield and quality. Plant growth and flowering habit can be a function of many factors including genotype, population density, winter survival, and growing conditions. This project is designed to develop cost-effective agronomic practices for commercial scale production St. John's Wort in Saskatchewan. Emphasis is placed on reducing manual labour through mechanization while maximizing yield and improving quality.

Effect of Plant Spacing and Harvest Height on Winter-kill and Productivity of St. John Wort, Cultivars grown under Irrigation and Dryland:

- Soil salinity caused significant yield depression in herb yields in all cultivars. Yields decreased progressively with time under this poor soil condition.
- Cultivars Elixir and Topas suffered less winter-kill, grew more vigorously, and produced higher herb yields than Helos, New Stem and Standard St. John's wort.
- When planted in 60 cm rows, 15 cm between plant spacing within the row produced higher herb yields than 30 cm within-row spacing.

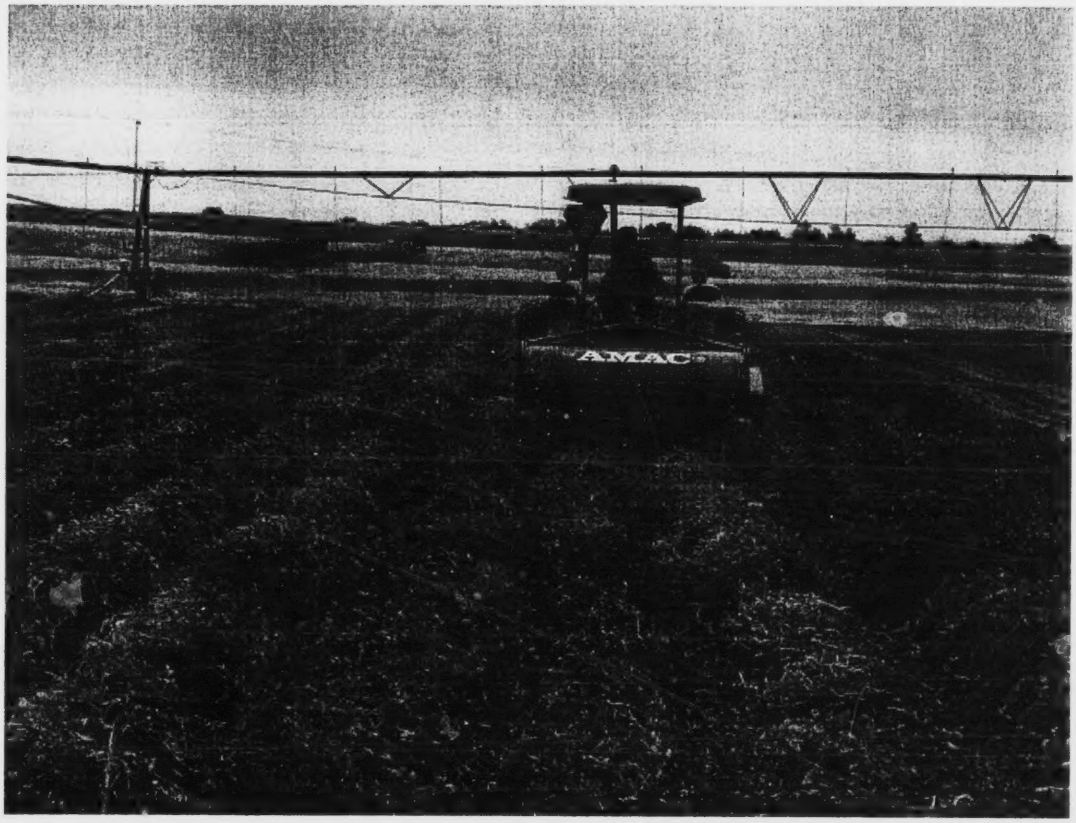
Effect of Nitrogen Application and Straw Mulching on Winter-kill and Productivity for St. John Wort's Cultivars Grown Under Irrigation and Dryland:

- St. John's wort cultivars suffered severe winter-kill and the incidence was more pronounced under dryland production relative to irrigated production. After two years of field production, the dryland crop had negligible survival. Under irrigation, an average survival rate of 36% to 60% was observed depending on the cultivar. Elixir and Topas recorded the highest survival of 59%-60% from the original stand.
- Mulching reduced winter-kill and increased herb yield under dryland but had no effect under irrigated production.
- Nitrogen application caused significant winter-kill and yield reduction in all cultivars under both dryland and irrigated production. This effect was more pronounced under higher nitrogen application rate.

Effect of Straw Mulch, Harvest Height and Harvest Frequency on Dry Herb Yield for St. John's Wort cultivars Grown Under Irrigation and Dryland:

- The incidence of winter kill and dry herb yields of St. John's wort cultivars Topas, Helos, Elixir, New Stem, and Standard varied from year-to-year and growing condition, i.e. irrigation or dryland.
- Herb yields were generally higher and winter-kill incidence was less under irrigated production compared to dryland production. Under dryland, there could be complete winter-kill.
- Under dryland, only one cut was possible in a season. However, Under irrigation two cuts were possible when the season was favourable (i.e. warm summer and fall) whereas, only one cut was possible when the growing season was cooler.
- Under irrigation, herb yields were generally similar when harvest was taken at a higher level (Top-1/3) or at a lower level (Top-2/3). By contrast, under dryland, lower cutting height produced higher herb yields than higher cutting height.
- Straw mulching reduced the incidence of winter-kill. Straw mulch was more beneficial for dryland than for the irrigated crop.

Harvest Management of Irrigated and Dryland Seed Potato Crop and the Impact on Productivity of Progeny



Jazeem Wahab and Greg Larson

Project Background:
The concept of Northern Vigour™ and high quality disease-free seed potato produced in the cooler northern Saskatchewan environments has made Saskatchewan a major player in the seed potato industry in North America and around the world. Consequently, seed potato production has become one of the major horticultural industries in Saskatchewan.

In recent years, Saskatchewan grown seed potato is in great demand in Alberta, Manitoba, Prince Edward Island, the Pacific North Western USA and Mexico. Smaller amounts of seed potato have also been shipped to several offshore markets. Quality of seed potato is vital for successful potato production and marketing. Quality characteristics of a superior seed stock include greater physiological vigour, freedom from tuber-borne diseases, and uniform tuber size grade as demanded by the target market. Appropriate production and storage management practices are necessary to produce disease-free, physiologically vigorous seed-tubers of specific size grades demanded by the target market.

Project Objectives:
Productivity of seed potato is a function of physiological vigour of the tuber and the presence/absence of tuber-borne diseases. Physiological vigour in turn is a combination of the inherent productivity of the seed-tuber and the influence of external conditions under which the seed crop is grown and stored. Physiologically younger seed-tubers are considered to be more productive than physiologically old seed-tubers. Physiological age is a manifestation of heat unit accumulation and/or the degree of stress the seed crop has experienced from tuber initiation through, tuber development, and during storage.

Commercial potato growers demand specific size grades. As such, the seed crop should be raised appropriately, top-killed and harvested at a suitable time to produce high quality seed-tubers of the required size grade as demanded by the buyers.

This project was designed to develop suitable harvest management practices to produce high quality (uniform size grade with high productive capacity and) seed potato in Saskatchewan. The study examined the effects of harvest management practices, i.e. flailing, chemical desiccation, and desiccation timing, on physiological condition of seed potato and productivity of seed lots for commercially important potato cultivars such as Atlantic, Russet Burbank, Russet Norkotah, Dark Red Norland, Ranger Russet, Shepody. Comparisons were made under both irrigated and dryland production in order to provide information to both irrigated and dryland producers in Saskatchewan. This study consisted of two components: (i) determine the effects of top-kill method, top-kill timing, and seed growing condition on seed grade tuber yield and (ii) the effects of top-kill method (flailing, flailing + desiccation) and timing (early and late), seed-tuber grade (Grade A and Grade B) and seed growing condition (dryland and irrigation) on productivity of progeny.

Field trials were carried out in the field plots of the Canada-Saskatchewan Irrigation Diversification Centre, Outlook during the summers 2002 through 2005. This project consisted of two studies:

i. Top-kill Study:
    Examine the effects of top-kill methods and harvest stages on yield and tuber size distribution for dryland and irrigated potato.

ii. Productivity evaluation of progeny

Effects of top-kill methods, top-kill dates, and growing condition of the seed crop on productivity of the progeny.

Seed-tubers harvested from the Top-kill study were stored at uniform storage temperature (4°C) were utilized to evaluate productivity in the following year. Consequently, Top-kill study was conducted 2002 through 2004, and progeny evaluation was conducted 2003 through 2005.

Effects of Top-Kill Methods and Harvest Stages on Seed Grade Tuber Yield for Dryland and Irrigated Potato.

Summary

2002:
Results indicated that irrigated production produced higher seed-grade yields than dryland production. Delaying top-kill produced higher yields.

2003:
Irrigated potatoes produced higher seed grade tuber yields at all three top-kill dates than dryland production. Potatoes top-killed by flailing or by chemical desiccation produced similar seed grade yield across all top-kill dates under both growing conditions. Seed grade tuber yields increased with delaying of desiccation dates. Yield rankings were somewhat similar across the various desiccation dates under irrigated and dryland production. Dark Red Norland produced the highest yield and Ranger Russet produced the lowest tuber yields during all top-kill dates and both growing conditions.

2004:
Irrigated potatoes produced higher seed grade than the dryland crop. Potatoes top-killed by flailing or by chemical desiccation produced similar seed grade yield across all top-kill dates under both growing conditions. The yield differences were more pronounced when top-killed at 90 DAP compared to later top-kill. Under dryland production, delaying top-kill resulted in higher seed grade yield relative to irrigated production. Dark Red Norland produced the highest yield across all harvest dates under both irrigated and dryland production. Under dryland, cultivar yield rankings were similar for all top-kill dates. However under irrigation, the cultivar yield rankings were variable among the various top-kill dates.

Study description:

Study period:	2002, 2003, 2004
Cultivars:	Norland, Russet Burbank, Russet Norkotah, Ranger Russet, Shepody, Atlantic
Top-kill method:	1. Flail, apply Reglone, and harvest 2 WAD 2. Apply Reglone on flailing date, and 7-10 days later
Top-kill stage:	Early, Mid and Late

Growing condition: Irrigation, dryland

Experimental Design: Split-plot design with four replications
Main-plot: Top-kill methods (2)
Sub-plot: Cultivar (6)
Separate trials for irrigation and dryland.

Methodology:

Seed piece size approximately 50 g
Planting dates: May 23, 2002; May, 26, 2003, May 18, 2004
Plot length = 6 m
Row spacing = 91 cm
Seed piece spacing = 30 cm
Seed pieces per row = 20
Fertilizer application: 200 kg N/ha (half at planting and half at hilling), 60 kg P_2O_5/ha, 50 kg K_2O/ha;
Pest control: Standard practices
Rainfall: 2002- 145 mm
2003- 82 mm
2004- 289 mm
Irrigation: Maintain soil moisture level above 50% Field capacity for the irrigation trials.
Irrigation applied for the irrigation trials:
2002- 365 mm
2003- 405 mm
2004- 140 mm
Top-kill method: - Flailing: Flail+Reglone (1.73 l/ha in 455 l water) Spray Reglone immediately after flailing
- Chemical desiccation: Reglone first application (2.22 l/ha in 455 l water). Reglone second application 5-7 days later (1.24 l/ha in 455 l water)
Top-kill stage: 2002- 100, 107, 114 days after planting
2003- 90, 97, 104 days after planting
2004- 90, 97, 104 days after planting
Harvest date: When vines are sufficiently dry and adequate tuber skin set
Grading: Size grades: Oblong tubers:
Grade B: 30 mm - 45 mm
Grade A: 45 mm - 70 mm
Round tubers:
Grade B: 30 mm - 50m
Grade A: 50 mm - 80 mm

Results

2002:

Top-killing at 100 days, on the average produced 28.7 t/ha seed grade yield under irrigation and 21.8 t/ha under dryland (Table 1). Delaying top-kill dates from 100 to 107 and 114 days after planting produced higher yields.

Irrigated production produced higher yields than dryland across all harvest dates (Table 1). The yield differences between dryland and irrigation at the various top-kill dates varied between 5 and 6 t/ha.

Top-killing the seed potato crop by (i) flailing followed by Reglone application or (ii) desiccating with two applications of Reglone produced similar seed grade yields at all top-kill dates under both dryland and irrigated growing conditions (Table 1).

Early maturing Dark Red Norland, mid-season Russet Norkotah, and the chipping cultivar Atlantic produced higher seed-grade tuber yields than the late-maturing Ranger Russet and Russet Burbank during all top-kill dates under irrigated production and during the first two top-kill dates under dryland production (Table 1). Russet Burbank and Shepody produced the significantly lower yields than the other cultivars on the third top-kill date under dryland production.

2003:
Irrigated potatoes produced higher seed grade tuber yields at all three top-kill dates under both dryland and irrigated production (Table 2).

Potatoes top-killed by flailing or by chemical desiccation produced similar seed grade yield across all top-kill dates under both growing conditions (Table 2).

seed grade tuber yields increased with delaying of desiccation dates. Yield rankings were somewhat similar across the various desiccation dates under irrigated and dryland production (Table 2). Dark red Norland produced the highest yield and Ranger Russet produced the lowest tuber yields during all top-kill dates and both growing conditions.

2004:
Irrigated potatoes produced higher seed grade tuber yields at all three top-kill dates. The yield differences were more pronounced during early top-kill (90 DAP) compared to late top-kill (Table 3).

Under dryland production, delaying top-kill resulted in higher seed grade yields. For example, the average yield during 90 DAP top-kill was 20.7 t/ha. The 97 DAP top-kill produced 31% higher seed grade yield than the 90 DAP treatment, and the 104 day top-kill produced 21% higher yield than the 97 DAP top-kill. Under irrigation, the 97 DAP top-kill produced 22% higher yield than 90 DAP top-kill. Delaying top-kill by another seven days increased yield by only 3%.

Dark Red Norland produced the highest yield across all harvest dates under both irrigated and dryland production. Under dryland, cultivar yield rankings were similar for all top-kill dates. However under irrigation, the cultivar yield rankings were variable among the various top-kill dates (Table 3).

Potatoes top-killed by flailing or by chemical desiccation produced similar seed grade yield across all top-kill dates under both growing conditions (Table 3).

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Effects of Top-kill Methods, Top-kill Dates, and Growing Condition of the Seed Crop on Productivity of the Progeny.

Summary

2003:
Seed crops top-killed by flailing or chemical desiccation produced similar yields. Top-kill dates of the seed crop had no effect on the productivity of the progeny except for Russet Norkotah 100-day top-kill produced higher yields than 114 day top-kill. Productivity of seed potatoes obtained from dryland or irrigated production conditions were similar. Grade-A seed of Ranger Russet, Russet Norkotah, and Shepody produced higher yields than Grade-B seed. For the other cultivars, both seed grades produced similar 'consumption' grade yields.

2004:
Seed tubers from crops top-killed either by flailing or by chemical desiccation and top-killed at different dates produced similar yields for all cultivars. Dryland and irrigated seed crops when planted produced similar consumption grade yields. Seed size grade had no effect on productivity except for Norland and Atlantic where Grade A seeds outyielded Grade B seed.

2005:
Seed crops top-killed by flailing or chemical desiccation produced similar yields. Top-kill date had no effect on productivity for DR Norland, Shepody, Russet Norkotah and Atlantic. However late top-killed seed crops of Russet Burbank and Ranger Russet, outyielded the early top-killed seed crop. Except DR Norland, seed crops raised under irrigation produced higher consumption grade yields than the seed crop raised on dryland. Yield responses for the different seed grade was variable.

Study Description:

Study period:	2003, 2004, 2005
Cultivars:	Norland, Russet Burbank, Russet Norkotah, Ranger Russet, Shepody, Atlantic
Top-kill method:	Flail, apply Reglone, and harvest 2 WAD Apply Reglone on flailing date, and 7-10 days later
Top-kill date:	Early: 100 DAP in 2003 and 90 DAP in 2004 and 2005 Late: 114 DAP in 2003 and 104 DAP in 2004 and 2005
Growing condition:	Irrigation, dryland
Seed grade:	Canada Grade A, Canada Grade B
Experimental Design:	2 (Top-kill method) x 2 (Top-kill date) x 2 (Growing condition) x 2 (Seed grade) factorial with four replications for each cultivar.

Methodology: Seed piece size approximately 50 g
Planting dates: June 3, 2003; May 18, 2004; May 25, 2005

Plot length = 6 m
Row spacing = 91 cm (36 in)
Seed piece spacing = 30 cm
Seed pieces per row = 20

Rainfall:	2003- 82 mm 2004- 289 mm 2005- 157 mm
Irrigation:	Maintain soil moisture level above 50% Field capacity for the irrigation trials Irrigation applied for the irrigation trials: 2003- 405 mm 2004- 140 mm 2005- 340 mm
Top-kill date:	Approximately 110 days after plantin
Harvest date:	Approximately two weeks after top kill
Grading:	45-90 mm size grade

Results

2003:
Table 4 summarizes the effects of the agronomic practices during the seed production season on the productivity of the progeny for commercial table, french fry and chipping potatoes. Different cultivars responded differently to the effects of seed production agronomy on 'consumption' grade yields.

Following is the summary of results:
- Seed crops top-killed by flailing or chemical desiccation produced similar yields.
- Russet Norkotah seed crop top-killed 100 days after planting produced higher yields than the seed crop top-killed 114 days after planting. For other cultivars, top-kill dates of the seed crop had no effect on the productivity of the progeny.
- Productivity of seed potatoes obtained from dryland or irrigated production conditions were similar for the various cultivars.
- Grade-A seed of Ranger Russet, Russet Norkotah, and Shepody produced higher yields than Grade-B seed. For the other cultivars, both seed grades produced similar 'consumption' grade yields.

2004:
Table 5 summarizes the effects of the agronomic practices during seed production season on the productivity of the progeny for commercial table, french fry and chipping potatoes. Cultivars responded differently to the effects of seed production agronomy on 'consumption' grade yields.

The results are summarized as follows:
- Seed tubers from crops top-killed either by flailing or by chemical desiccation produced similar yields for all cultivars,
- Seed tubers from crops top-killed at different dates produced similar yield for all cultivars
- Productivity of seed potatoes obtained from dryland or irrigated production were similar for the various cultivars, and
- Grade A seed of Dark Red Norland and Atlantic produced higher yields than Grade B seed. For the other cultivars, both seed grades produced similar 'consumption' grade yields.

2005:

Table 6 summarizes the effects of the agronomic practices during seed production season on the productivity of the progeny for commercial table, french fry and chipping potatoes. Cultivars responded differently to the effects of seed production agronomy on 'consumption' grade yields.

The results are summarized as follows:

- Seed crops top-killed by flailing or chemical desiccation produced similar yields.
- Top-kill date had no effect on productivity for DR Norland, Shepody, Russet Norkotah and Atlantic. However late top-killed seed crops of Russet Burbank and Ranger Russet, outyielded the early top-killed seed crop.
- Except DR Norland, seed crop of all other cultivars raised under irrigation produced higher yields than the seed crop raised on dryland, but the yield differences for Shepody were not significant
- Yield responses for the different seed grade was variable. Grade A seed of Dark Red Norland produced higher yield than Grade B seed. By contrast Grade B seed of Russet Norkotah produced higher yield than Grade A seed. Other cultivars showed no yield differences with the two different seed classes.
- The first and second order interactions for the various cultivars did not show any logical trends.

Table 1. Effects of top-kill method and timing on seed grade yield for commercial potato cultivars grown under dryland and irrigation: 2002						
	Irrigation yield (t/ha)			Dryland (t/ha)		
Treatment	100 DAP[1]	107 DAP	114 DAP	100 DAP	107 DAP	114 DAP
Top-kill method:						
Reglone	28.5	29.9	34.4	21.1	23.6	27.4
Flail	28.8	32.1	34	22.5	28.5	28.9
Cultivar:						
Atlantic	30.6	33.6	35.9	24.3	29.1	32.5
Russet Burbank	24	25	25.3	16.6	20.5	18.7
Russet Norkotah	31.5	30.2	32.4	26.2	28.4	30.5
D. Red Norland	30.8	34.4	39	22.6	27.3	31.4
Ranger Russet	26.5	28.1	33.4	20.2	24.2	28.5
Shepody	28.4	34.9	39.1	21.1	27.1	27.5
Analyses of Variance						
Source:						
Treatment (T)	ns	ns	ns	ns	ns	ns
Cultivar (C)	**(3.7)	***(3.6)	***(4.0)	***(2.5)	***(3.0)	***(4.3)
T x C	ns	ns	ns	ns	ns	ns
C.V.	12.7	11.5	11.5	11.3	11.4	15.3

[1]Days after planting.
, * and ns indicate significance at P< 0.01, 0.001 levels of probability and not significant respectively. Values within parentheses are LSD estimates at 5.0% significance.

Table 2. Effects of top-kill method and timing on seed grade yield for commercial potato cultivars grown under dryland and irrigation: 2003						
Treatment	Dryland/Top-kill date			Irrigation/Top-kill date		
	90 DAP[1]	97 DAP	104 DAP	90 DAP	97 DAP	104 DAP
	---Tuber yield (t/ha)---					
Top-kill:						
Reglone 2X	24.4	28.6	31	39.2	43.3	45.6
Flail + Reglone	23.5	29.5	30.7	38.8	45.8	47.2
Cultivar:						
Atlantic	32.3	36.1	34.2	45.9	51.5	50.1
Russet Burbank	20.4	22.1	29	30.7	40.5	41.9
Russet Norkotah	22.8	32.4	34.7	41.5	43.9	46.4
Dark Red Norland	35.2	41.5	39.8	52.1	56.2	60.1
Ranger Russet	13.9	19.4	21.1	30	34.6	36.8
Shepody	19.4	22.9	26.4	34	40.6	43.3
Analyses of Variance						
Source						
Desiccation	ns	ns	ns	ns	ns	ns
Cultivar	**(10.2)	***(3.8)	***(3.5)	***(5.1)	***(5.2)	***(4.3)
Cultivar x Desiccation	ns	ns	ns	ns	ns	ns
C.V. (%)	41.8	12.7	11.0	12.9	11.6	9.0

[1]Days after planting.
, *, and ns indicate significance at P<0.01 and 0.001 levels of probability and not significant respectively.
Values within parentheses are LSD estimates at 5.0% level of significance.

Table 3. Effects of top-kill method and timing on seed grade yield for commercial potato cultivars grown under dryland and irrigation: 2004

Treatment	Dryland Top-kill date			Irrigation Top-kill date		
	90 DAP[1]	97 DAP	104 DAP	90 DAP	97 DAP	104 DAP
	---------------------------Tuber yield (t/ha)------------------------------					
Top-kill:						
Reglone	20.7	24.8	32.5	28	33.9	35.4
Flail + Reglone	20.7	29.5	33	28.4	35	35.7
Cultivar:						
Atlantic	18.9	25.4	31.1	30.1	34.8	33.4
Dark Red Norland	29.8	34.7	38.6	37.9	42.4	44.4
Ranger Russet	15.7	23.3	29.8	25.1	27.1	32.5
Russet Burbank	19.5	25.5	33	24.6	34.1	30.9
Russet Norkotah	22.9	28	33.6	28.7	35.5	39.2
Shepody	17.5	25.1	30.2	22.9	32.6	32.8
Analyses of Variance						
Source						
Desiccation	ns	ns	ns	ns	ns	ns
Cultivar	**(2.9)	***(4.1)	***(4.3)	***(3.5)	***(5.8)	***(4.5)
Cultivar x Desiccation	ns	ns	ns	ns	ns	ns
C.V. (%)	13.9	15.0	12.8	12.2	16.5	12.0

[1] Days after planting

, *, and ns indicate significance at $P<0.01$ and 0.001 levels of probability and not significant respectively.

Values within parentheses are LSD estimates at the 5.0% level of significance.

Table 4. Effects top-kill method and timing, growing condition, and seed-tuber grade on 'consumption' grade yield of the progeny for six commercial potato cultivars: 2003

Treatment	Russet Burbank	Dark Red Norland	Shepody	Russet Norkotah	Ranger Russet	Atlantic
Top-kill method:						
Flail	28.3	37.8	32.7	41.2	26.3	43.8
Reglone	28.1	38.5	33.7	41.9	26.9	44.9
Top-kill date:						
100 DAP[1]	28.3	37.7	33.3	43	25.3	44.3
114 DAP	28	38.5	33.1	40	27.9	44.4
Growing condition:						
Dryland	27.6	38.6	33.1	41.8	27.4	44.5
Irrigation	28.8	37.7	33.3	41.2	25.7	44.1
Seed grade:						
Grade A	27.6	38.9	34.4	44	29	45
Grade B	28.7	37.4	32	39.1	24.1	43.7
Analyses of variance						
Source:						
Top-kill method (M)	ns	ns	ns	ns	ns	ns
Top-kill date (D)	ns	ns	ns	*	**	ns
Growing condition (G)	ns	ns	ns	ns	ns	ns
Seed grade (S)	ns	ns	*	***	***	ns
M x D	*	ns	ns	ns	ns	ns
M x G	ns	ns	ns	ns	ns	ns
M x S	ns	ns	ns	**	ns	ns
D x G	ns	ns	ns	*	ns	ns
D x S	ns	ns	ns	ns	ns	ns
G x S	ns	ns	ns	*	ns	ns
M x D x G	ns	ns	ns	*	*	ns
M x D x S	ns	ns	ns	ns	ns	*
M x G x S	ns	ns	ns	ns	ns	ns
D x G x S	ns	ns	ns	**	ns	ns
M x D x G x S	ns	ns	ns	ns	ns	ns
C.V (%)	14.7	11.1	13.8	12.4	13.1	9.5

[1]Days after planting.
*, **, *** indicate significance at P<0.05, 0.01,0.001 levels of probability and not significant respectively.

Table 5. Effects top-kill method and timing, growing condition, and seed-tuber grade on 'consumption' grade yield of the progeny for six commercial potato cultivars: 2004

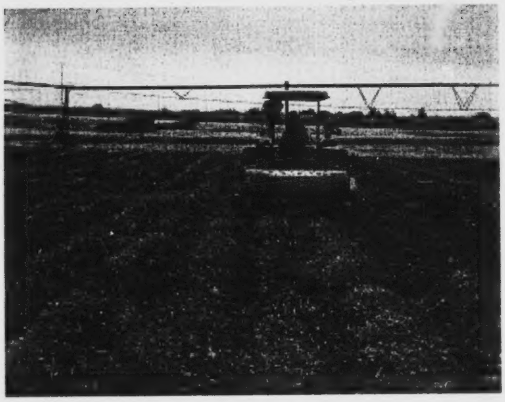
Treatment	Russet Burbank	Dark Red Norland	Shepody	Russet Norkotah	Ranger Russet	Atlantic
Top-kill method:						
Flail	32.5	46.7	41.8	44.7	36.6	37.8
Reglone	32.9	47	42.9	44.2	35.6	37.9
Top-kill date:						
90 DAP[1]	32.1	46.9	41.7	44.2	35.3	37.4
104 DAP	33.3	46.8	42.9	44.6	36.8	38.2
Growing condition:						
Dryland	32.3	47	42.8	43.5	36	38.6
Irrigation	33	46.7	41.8	45.4	36.2	37
Seed grade:						
Grade A	31.8	50.2	43.3	45.7	36.1	38.8
Grade B	33.5	43.5	41.3	43.2	36.1	36.9
Analyses of variance						
Source:						
Top-kill method (M)	ns	ns	ns	ns	ns	ns
Top-kill date (D)	ns	ns	ns	ns	ns	ns
Growing condition (G)	ns	ns	ns	ns	ns	ns
Seed grade (S)	ns	***	ns	ns	ns	*
M x D	ns	ns	ns	ns	ns	ns
M x G	ns	ns	ns	ns	ns	ns
M x S	ns	ns	ns	ns	ns	ns
D x G	ns	ns	ns	ns	ns	ns
D x S	ns	ns	ns	ns	ns	***
G x S	ns	ns	ns	ns	ns	*
M x D x G	ns	ns	ns	ns	ns	**
M x D x S	ns	ns	ns	ns	ns	ns
M x G x S	ns	ns	ns	ns	ns	*
D x G x S	ns	ns	*	ns	ns	ns
M x D x G x S	ns	ns	ns	ns	ns	ns
C.V (%)	12.2	11.0	11.9	11.8	10.5	10.2

[1]Days after planting.
*, **, *** indicate significance at P<0.05, 0.01,0.001 levels of probability and not significant respectively.

Table 6. Effects top-kill method and timing, growing condition, and seed-tuber grade on 'consumption' grade yield of the progeny for six commercial potato cultivars: 2005

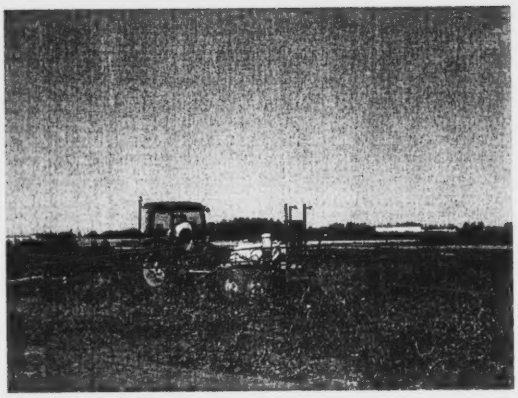
Treatment	Russet Burbank	Dark Red Norland	Shepody	Russet Norkotah	Ranger Russet	Atlantic
Top-kill method:						
Flail	42.3	55.5	44.9	47	44.4	41.8
Reglone	41.7	55.4	45.5	46.7	44.1	52
Top-kill date:						
90 DAP[1]	40.2	55.7	45.1	47.3	43.7	52.5
104 DAP	43.8	55.2	45.3	46.4	45.7	51.3
Growing condition:						
Dryland	40.7	56.5	44.6	45.9	42.4	50.9
Irrigation	43.3	54.3	45.7	47.8	46.1	52.9
Seed grade:						
Grade A	41.3	51.5	45.3	47.7	44.9	50.9
Grade B	42.8	59.4	45.1	46	43.5	52.9
Analyses of variance						
Source:						
Top-kill method (M)	ns	ns	ns	ns	ns	ns
Top-kill date (D)	***	ns	ns	ns	**	ns
Growing condition (G)	***	*	ns	*	***	ns
Seed grade (S)	ns	***	ns	*	ns	ns
M x D	ns	ns	ns	ns	ns	ns
M x G	ns	ns	ns	ns	ns	ns
M x S	ns	ns	ns	ns	ns	ns
D x G	ns	*	ns	ns	ns	ns
D x S	***	ns	*	*	**	ns
G x S	**	ns	*	ns	ns	ns
M x D x G	**	ns	ns	ns	ns	ns
M x D x S	ns	ns	ns	ns	ns	ns
M x G x S	ns	*	ns	*	ns	ns
D x G x S	ns	**	ns	ns	ns	ns
M x D x G x S	ns	ns	ns	ns	ns	ns
C.V (%)	8.3	11.0	10.8	6.7	8.2	10.8

[1]Days after planting
*, **, *** indicate significance at P<0.05, 0.01,0.001 levels of probability and not significant respectively.



Flailing potato.

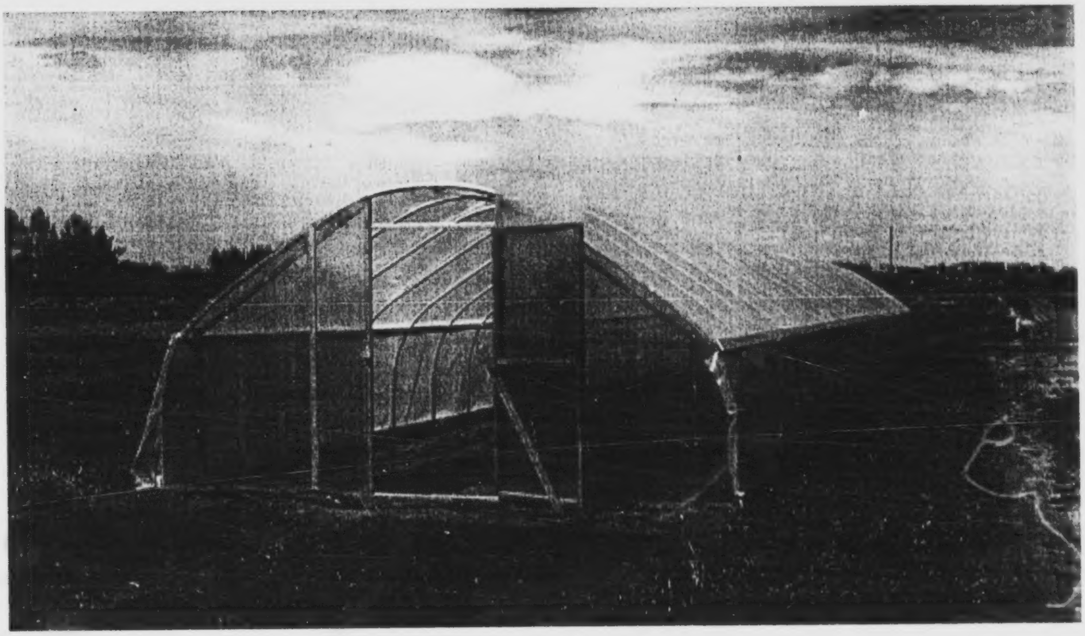
Potato: Immediately after flailng.



Spraying Reglone.

Non flailed potato desiccated with Reglone.

Season Extension Demonstration



B.Vestre, T. Hogg, and J. Wahab

Summary

Season extension techniques for the production of warm season vegetable crops are becoming more prominent in Saskatchewan. In 2004, the Canada-Saskatchewan Irrigation Diversification Centre completed demonstrations aimed at maximizing production and economic return for cantaloupe and pepper utilizing a method of season extension commonly referred to as a "high tunnel". High tunnels are essentially plastic covered greenhouses constructed in the field with no artificial heating or ventilation (Figure 1). Ventilation is achieved by rolling up the sides of the high tunnel.

Agronomic demonstrations included a green pepper plant population study and cantaloupe plant population and planting material (transplant vs. direct seeding) studies. The green pepper study compared 15cm, 30cm, and 60cm in-row spacings at a 30cm between row spacing. The cantaloupe study compared 30cm and 60cm in-row spacings at a 60cm between-row spacing using both direct seeding and transplants. Irrigation was supplied with trickle tape.

Pepper yields increased with closer in-row spacings. Average yields in 2003 and 2004 were 14.8 kg/m double row, 12.3 kg/m double row, and 9.5 kg/m double row for the 15cm, 30cm, and 60cm in-row spacings respectively. The yields include all market classes of peppers. Total yields were comparable for all spacings in 2003 and 2004. However, only 40% of the peppers matured to red color in 2004 as compared to close to 80% in 2003. Gross returns in 2003 were $41/m double row, $33/m double row, and $23/m double row for the 15cm, 30cm, and 60cm in-row spacings respectively. Returns were $34/m double row, $28/m double row, and $23/m double row respectively in 2004.

Cantaloupe yields were variable. In 2003, the early transplants and direct seeding produced yields of 5 kg/m² and 6 kg/m² respectively. Yields declined dramatically with later seeding dates with a yield of 1 kg/m² for the June 6th seeding date. There was no significant difference in 2003 between the 12" and 24" spacings. In 2004, due to poor growing conditions, no melons were harvested from inside the high tunnel.

Background

Warm season high value crops such as cantaloupe and peppers are difficult to produce under Saskatchewan climatic conditions without using some form of season extension. High tunnels significantly alter the growing conditions of crops. Growing Degree Days are higher in the high tunnel as compared to growing conditions outside the tunnels (Figure 2). In order to maximize production with these favorable growing conditions, optimum plant population, fertility management, planting date(s), and planting practices need to be refined.

Objective

To demonstrate the effect of green pepper plant population and cantaloupe plant population and planting material (direct seed vs transplants) on yield and economic return.

Study Description

The green pepper plant population demonstration was grown in high tunnel #3 in 2003 and #2 in 2004. Due to an early killing frost, the results from 2002 will not be discussed. Fertilizer applications in the tunnels were based on soil test recommendations. Four lengths of infra red transmissible (IRT) plastic mulch were evenly spaced across the 6 metre wide tunnel with an

irrigation drip tape underneath.

"Whopper Improved" green pepper was seeded in the greenhouse in mid-April in 72 square seedling flats. These were transplanted in mid to late May in the high tunnel at row spacings of 15cm, 30cm, and 60cm in a double row configuration for each mulch strip. Floating row covers were placed over the peppers to provide extra frost protection. Irrigation was provided using trickle tape.

The cantaloupe plant population and direct seeding vs. transplant demonstration was grown in high tunnel #2 in 2003 and #3 in 2004. Fertilizer applications in the tunnels were based on soil test recommendations. Four lengths of IRT mulch were evenly spaced across the 6m wide tunnel along with drip tape under the mulch. Transplanting and the first direct seeding were conducted in early May. Floating row covers were placed over the plants to provide extra frost protection. Direct seeding continued for the next 4 consecutive weeks. Cantaloupe transplants and seeds were planted at 30 cm and 60 cm in-row spacings utilizing a double row configuration on each mulch strip. Irrigation was applied using drip tape. Honey bees were placed inside the tunnel for pollination. Melons were harvested at full slip.

Results

Yield and quality of the pepper crop in both 2003 and 2004 was excellent. There were significant yield differences between the 15 cm, 30 cm, and 60 cm plant spacings. There was no significant yield difference between years (Table 1). There was, however, a significant difference in the percentage of red peppers. In 2003, 80% of the pepper crop matured to red while in 2004 only 40% matured to red. The warmer than normal summer in 2003 and the cooler than normal summer in 2004 affected the maturation of the crop. This is significant because the price of red market peppers tends to be much higher than that of green market peppers resulting in a higher gross return (Table 2) and higher net economic returns (Table 3). With a standard 29m x 6m (96' x 20') high tunnel and 8 planted rows on a 15cm spacing, net returns ranged from $1600/tunnel to $2600/tunnel depending on weather conditions.

The cantaloupe plant population and transplant vs. direct seeding demonstration benefitted greatly from the warm summer in 2003. The early transplants and direct seeding produced higher yields and higher gross returns than the late seeded crop (Table 4). The later seeded crops produced excess vegetative growth with little fruit development. The cantaloupe crop did not produce well in 2004. Despite being inside the high tunnel, the fruit did not mature resulting in no harvestable yield.

Conclusion

Pepper yields inside high tunnels increase with closer in-row spacings with no significant difference in quality. Net economic returns, despite utilizing season extension technology such as high tunnels, can still be affected by climatic conditions. A warmer than normal year will result in a high percentage of the pepper crop maturing to red, thus increasing economic returns. A cooler than normal year will be result in less maturation, and lower economic return.

Cantaloupe yields inside high tunnels were quite variable. In this demonstration, early direct-seeding at 30cm spacing under "normal" climatic conditions resulted in the highest yields. Transplanting did not have the desired result of earlier maturity as compared to the direct seeding. This was mainly due to "transplant shock" of the plants. Within a two to three week period, the direct seeded plants were at the same stage of growth as the transplants. The

added expense of producing transplants was not cost effective.

Sequential planting did not have the desired effect. By increasing and spreading out planting dates, we hoped to lengthen the marketing period. This did not occur. The later planting dates resulted in lower fruit set and subsequently fewer mature fruit.

The economics of producing cantaloupes in a high tunnel are questionable. In this demonstration, using wholesale prices, the highest gross economic yield was $8.00/m². This was from the early direct-seeded, 30cm plant spacing treatment. At this yield and price, the net economic return on a standard 6m x 29m tunnel is -$63.00.

In order to make production of cantaloupe inside high tunnels economical, both yield and price must be substantially higher. In this demonstration, the melons were sold into the wholesale market and the price received is two to three times less than that received by direct selling. The method of marketing is a major factor in successful economic production of cantaloupe under high tunnels. Maximizing total yields of melons is also a challenge. Excellent plant growth did not result in excellent fruit production. Factors such as soil fertility, temperature control, and cultivar selection for high tunnel production need to be addressed.

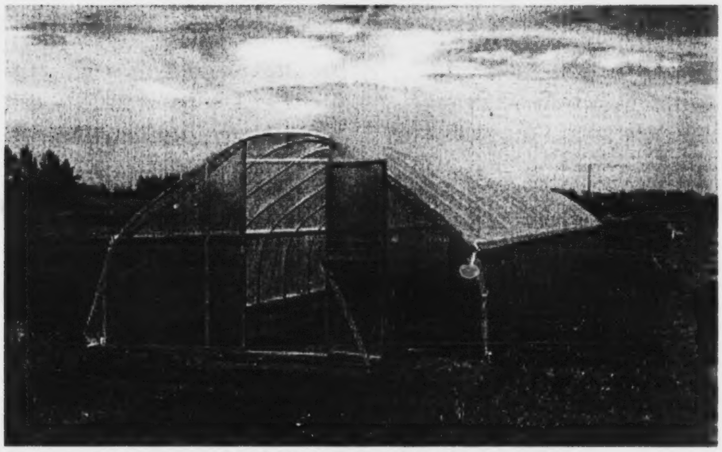


Figure 1. 4.3 m x 29 m' High tunnel at the Canada-Saskatchewan Irrigation Diversification Centre.

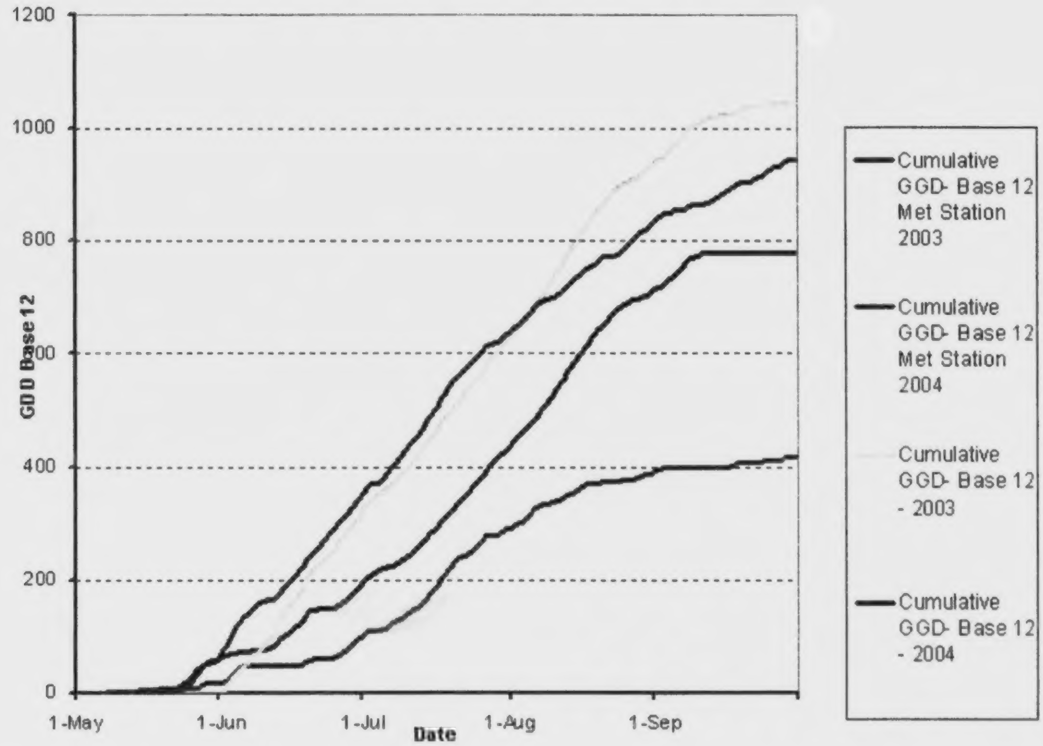


Figure 12 . Cumulative Growing Degree Days Inside vs Outside in 2003 and 2004

Table 1. Yield of pepper market classes under high-tunnel production												
Spacing	Yield (kg/m double row)										% Red Market	
	Red Market		Green Market		Red Choppers		Green Choppers		Total Yield			
	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004
15 cm	11.4	6.3	2	6.2	0.9	0.9	0.1	0.9	14.4	14.3	79	44
30 cm	9.3	4.8	1.1	5.5	0.9	1.2	0.4	1.2	11.7	12.7	80	38
60 cm	6.6	3.7	0.4	5.4	0.6	0.7	0.2	0.7	7.8	10.5	85	35

Table 2. Gross Returns ($/m double row)

Table 2. Gross returns for pepper market clsses under high-tunnel production										
Spacing	Gross return ($/m double row)									
	Red Market		Green Market		Red Choppers		Green Choppers		Total Gross Return	
	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004
15 cm	36.3	20	3.9	11.4	1	1.1	0.1	1.1	41	31
30 cm	29.6	15.3	2.1	11.1	1.1	1.5	0.5	1.5	33	28
60 cm	21	11.8	0.8	9.9	0.7	0.9	0.2	0.9	22	23
Market Price Received: Red Market- $3.18/kg; Green Market: $1.84/kg; Red and Green Choppers: $1.22/kg										

Table 3.	Net Returns for Pepper Production in High Tunnel (29m x 6m) or (4 double rows, 28m each)			
			High	**Low**
Revenue			$41	$31
	Peppers		$4,500	$3,500
	Total Revenue		**$4,500**	**$3,500**
Expenses				
	High Tunnel ($7000/20yrs)	$350		
	Fertilizer & Chemical	$50		
	Mulch and Drip Tape	$25		
	Seed and Transplants	$100		
	Tillage	$50		
	Labour			
	Soil Prep	$100		
	Seeding and Planting	$300		
	Weeding	$100		
	Harvesting and Packing	$300		
	Marketing	$400		
	Packaging	$100		
	Total Expenses		$1,875	$1,875
	Net Economic Return		**$2,625**	**$1,625**

Table 4. Cantaloupe yields and gross returns under high-tunnel production

Treatment	TOTAL COUNT	TOTAL WEIGHT kg	AVERAGE WEIGHT kg/fruit	TOTAL YIELD kg/m²	Gross Return $/m²
Transplant- 12" / May 7	66	81	1.23	5.78	6.35
Transplant- 24" / May 7	56	67	1.20	4.81	5.3
Direct Seed- 12 " May 7	72	102	1.41	7.26	8
Direct Seed- 24" May 7	56	81	1.44	5.78	6.35
Direct Seed- 12 " May 14	54	66	1.22	4.71	5.18
Direct Seed- 24" May 14	24	32	1.32	2.26	2.5
Direct Seed- 12 " May 22	36	44	1.21	3.12	3.4
Direct Seed- 24" May 22	12	15	1.29	1.11	1.22
Direct Seed- 12 " May 29	18	25	1.37	1.76	1.93
Direct Seed- 24" May 29	6	11	1.84	0.79	0.87
Direct Seed-12" June 6	9	14	1.49	1.00	1.1
Direct Seed- 24" June 6	9	15	1.69	1.09	1.2

Wholesale Price: $1.10/kg

Table 5.	Net Returns for Cantaloupe in High Tunnel (29m x 6m)		
Revenue			
	Cantaloupe		$1,392
	Total Revenue		**$1,392**
Expenses			
	High Tunnel ($7000/20yrs)	$350	
	Fertilizer & Chemical	$50	
	Mulch and Drip Tape	$25	
	Seed and Transplants	$10	
	Tillage	$50	
	Labour		
	Soil Prep	$100	
	Seeding and Planting	$20	
	Weeding	$50	
	Harvesting and Packing	$300	
	Marketing	$400	
	Packaging	$100	
	Total Expenses		$1,455
	Net Economic Return		**-$63**

Pumpkin Irrigation Scheduling Demonstration

Terry Hogg, Don David, Jazeem Wahab, Barry Vestre and Laurie Tollefson

Summary

A pumpkin irrigation scheduling demonstration trial was conducted at the Canada-Saskatchewan Irrigation Diversification Centre over a four year period 2002-2005 to determine the total water use and water use efficiency of pumpkin grown in a double row configuration using trickle irrigation and plastic mulch under Saskatchewan growing conditions. Pumpkin was grown using trickle tape and IRT plastic mulch in rows 135 m long with a 3 m row spacing.

Irrigation treatments consisted of irrigation initiation at a soil available water (A.W.) content of 85% A.W. (Water Treatment 1) and 70% A.W. (Water Treatment 2) and a dryland comparison. Irrigations were scheduled based on soil available water in the top 30 cm of the profile utilizing tensiometers. Soil moisture monitoring was conducted using a neutron moisture meter at varying intervals throughout the growing season.

Growing season conditions varied among the four years that the trial was conducted. In 2002 and 2003 conditions were warmer than average while in 2004 and 2005 conditions were cooler than average. Precipitation also varied among the years. Compared to the long term average 2002 had average precipitation, 2003 below average precipitation and 2004 and 2005 had above average precipitation. The warmer and dryer conditions in 2002 and 2003 resulted in high potential ET and provided growing conditions that were more conducive to irrigated pumpkin production than the cooler and wetter conditions in 2004 and 2005. Thus responses to the irrigation treatments varied among years and for this reason the results could not be combined over years.

Total water use for the growing season increased as the quantity of irrigation water applied increased and was of the order Water Treatment 1 > Water Treatment 2 > Dryland Treatment for all four years that the trial was conducted. Water use was highest in 2002 and 2003 when conditions were warmer and drier than average resulting in high potential ET and thus high demand for irrigation applications in order to maintain the soil water potential at the specified levels for the given treatments.The lower than average temperature and higher than average precipitation in 2004 and 2005 resulted in low potential ET and thus low demand for irrigation applications and low water use.

Yield response of the pumpkin to irrigation applications varied among the years the trial was conducted and appeared to be related to growing season conditions. In 2002 and 2003, when growing conditions were generally warmer and drier than average, pumpkin yield increased as the quantity of water applied was increased. Both irrigation treatments produced significantly greater pumpkin yield than the Dryland Treatment. Yield differences were due to pumpkin size but not the number of pumpkins produced. In 2004 and 2005, when growing conditions were cooler and wetter than average, pumpkin yields showed no response to the irrigation water applications. Yields in 2004 were low while the yields in 2005 were high with both years showing no significant yield differences due to the water treatments. As well, in both 2004 and 2005 the number of pumpkins produced per unit area, the mean pumpkin weight and the fruit size distribution also showed no significant differences among the water treatments. The cool wet growing conditions prevented the pumpkins that were produced from maturing properly (orange color change) and provided ideal conditions for the onset of disease and fruit rot in 2004. The high yield in 2005 would be considered a potential yield rather than a marketable yield since the majority of pumpkins that were produced did not mature but remained green late into the growing season.

Pumpkin yield increased as the water use increased in both 2002 and 2003 but showed no relationship to water use in 2004 and 2005. There was a significant relationship between pumpkin yield and water use for the years 2002 and 2003 in which growing conditions were warmer and drier than average and which showed a response to irrigation application. In 2004 and 2005, the cooler and wetter than average growing conditions resulted in a low demand for irrigation applications and thus there was no significant response of yield to total water use over the growing season.

Water use efficiency (kg pumpkin produced/mm water use) varied among the years and appeared to be related to growing conditions. In 2002 and 2003, where growing conditions favored a yield response to irrigation applications, water use efficiency decreased as the quantity of water applied was increased. In 2004 and 2005, where there was a low demand for irrigation applications and no significant response of yield to total water use over the growing season, water use efficiency showed little response to the different water application treatments. The efficiency with which water is used to produce dry matter must be balanced with the availability of water for irrigation when deciding on the best use of the water supply.

It is very clear from these results that adequate heat and moisture are required for optimum pumpkin production. Without adequate heat there will be no response to irrigation water applications.

Background

Moisture requirements for vegetables is high and therefore areas with limited water supply are restricted in their cropping decisions. Plasticulture techniques can lower the total water requirements of a crop. Data is required to determine water consumption and water efficiencies under Saskatchewan conditions using plasticulture techniques. This will assist producers with both limited and adequate water supplies to make sound irrigation and production management decisions.

Objective

To demonstrate irrigation scheduling and determine total water use and water use efficiency of pumpkin grown using trickle irrigation and IRT plastic mulch under Saskatchewan growing conditions.

Study Description

A pumpkin irrigation scheduling trial was established in the spring of each year from 2002-2005 at the Canada-Saskatchewan Irrigation Diversification Centre (CSIDC) located on the SW15-29-08-W3. The soil at the site, developed on medium-textured lacustrine deposits, was classified as Bradwell L - SiL. Each year the site received an application of fertilizer based on soil available nutrients levels. Nitrogen applied as 46-0-0, phosphorus applied as 12-51-0 and potassium applied as 0-0-60 were broadcast as required and incorporated to a depth of 8 cm.

IRT (infrared transmissible) plastic mulch and trickle tape (RoDrip 30 cm emitter spacing in 2002 and T-Tape TSX 506-08-670 20 cm emitter spacing in 2003-2005) were applied in a single operation in strips 135 m in length and on 3 m centers using a commercial mulch/trickle tape applicator (Figure 1). To make most efficient use of the mulch, pumpkin was seeded in a

double row configuration along the outer edges with the drip tape running between the two rows and below the plastic mulch. Pumpkin cv Spirit was hand seeded (2 seeds/hill) through the plastic mulch using a water wheel planter at a 0.9 m within row spacing and 0.6 m between row spacing on each mulch strip (Figure 2). Areas with poor plant emergence were re-planted using pumpkin transplants in order to maintain an optimum plant stand.

Irrigation treatments consisted of irrigation initiation to maintain soil available water (A.W.) content above 85% A.W. (Water Treatment 1) and above 70% A.W. (Water Treatment 2) and a dryland comparison. The irrigation treatments were arranged in a randomized complete block design with three replicates. Each individual plot consisted of one mulch strip. Nine mulch strips were installed to accommodate the number of treatments and replicates (Figure 3).

Irrigations were scheduled based on soil available water in the top 30 cm of the profile utilizing tensiometers. Three tensiometers were installed across the mulch strip (one in each pumpkin row and one next to the trickle line) to a depth of 30 cm at one location in each irrigated mulch strip (Figure 3). As well, one deep tensiometer, installed to a depth of 60 cm, was used to monitor the lower part of the root zone and determine if the quantity of water applied was sufficient to replenish the available water in the plant root zone. Irrigation was initiated for Water Treatment 1 and Water Treatment 2 to maintain the soil available water content above 85% and 70% respectively based on a wetting characteristic moisture release curve of the 0-30 cm depth determined by the Association of Analytical Communities (AOAC) approved Chilled Mirror Dewpoint technique using a Dew Point Potentiameter to measure soil water potential.

The quantity of irrigation water applied (mm) at each irrigation was calculated from the trickle tape emitter flow rate (L/hr), irrigation time interval (hr) and area irrigated (m^2), where, 1 mm water application = 1 L/m^2. The emitter flow rate was measured each year, except 2005, at three locations along four of the nine pumpkin strips by collecting the water from one emitter over a defined time interval (Figure 4). The emitter flow rate measurements were also used to determine the Lower Quarter Distribution Uniformity (LQDU). The LQDU was used to determine the uniformity of the irrigation water application in the trial area while the mean emitter flow rate (L/hr) value was used in calculating the amount of irrigation water applied. The time interval used and thus the quantity of irrigation water applied was dependent on the soil water holding capacity.

Soil moisture monitoring was conducted with a neutron moisture meter (Figure 5) at four locations (subsamples) in each pumpkin water treatment strip (Figure 6). Aluminum neutron access tubes were installed to a depth of 120 cm and readings conducted at 15 cm intervals except for the 0-15 cm interval. The moisture content of the 0-15 cm interval was measured by the time domain reflectometry technique using a TDR 300 soil moisture meter (Figure 7). Soil moisture was measured at the time of installation just after seeding, at varying intervals throughout the growing season and at harvest.

The total water content of the soil profile (0-120 cm) at each measurement time was calculated by adding the individual water contents of each depth interval measured (0-15 cm, 15-30 cm, 30-45 cm, 45-60 cm, 60-75 cm, 75-90 cm, 90-105 cm and 105-120 cm). Individual depth water content was calculated as follows:

$$\text{Soil Water Content (mm)} = (Pv * D)/100$$

Where,

Pv = % volumetric water

D = depth increment (mm)

The change in soil moisture content (mm) at each depth from one time period to the next was calculated from the difference between the moisture content at the beginning and the end of the time period. The calculation was as follows:

$$\text{Change in Soil Moisture Content (mm)} = ((Pv_{t1} * D)/100) - ((Pv_{t2} * D)/100)$$

Where,

Pv_{t1} = % volumetric water @ time 1

Pv_{t2} = % volumetric water @ time 2

D = depth increment (mm)

Profile moisture change for each measurement time period was calculated by adding the soil moisture change for each depth increment for the entire soil profile (0-120 cm). A positive value for the change in soil moisture content indicates water removed while a negative value indicates water added. Total water use for any given time period was calculated by adding rainfall for the time period, irrigation for the time period and the difference between the soil profile (0-120 cm) water content at the beginning and the end of the time period (profile moisture change). Total water use over the growing season (seeding to harvest) was calculated by summing the water use for each individual time period.

At harvest, yield estimates were obtained by weighing each individual pumpkin (Figure 8) from an area 10 m x 2 rows centered on each neutron access tube (subsamples).

Analysis of variance with subsamples was used to determine the significance of differences among the water treatments for total water use, yield, pumpkin number and mean pumpkin weight.

Results

Growing season conditions varied among the four years that the trial was conducted. Cumulative Growing Degree Days Base 10 $^{\circ}C$ (GDD_{10}) from May 15 to September 30 (Figure 9), an indication of heat received during the growing season, indicated that 2002 and 2003 were warmer than average (952 and 1035 GDD_{10} respectively) while 2004 and 2005 were cooler than average (630 and 737 GDD_{10} respectively). 2003 was the warmest year while 2004 was the coolest year during the four year period that the trials were conducted (Figure 10). Precipitation also varied among the years (Figure 11). Compared to the long term average (217 mm) 2002 was similar (189 mm), 2003 was below (130 mm) and 2004 (305 mm) and 2005 (391 mm) were well above average. The warmer and dryer conditions in 2002 and 2003 resulted in higher potential ET (Figure 12) and thus were more conducive to irrigated pumpkin production than were the cooler and wetter years of 2004 and 2005. Thus responses to the irrigation treatments varied among years and for this reason the results could not be combined over years.

Planting date, fertilizer application, Lower Quarter Distribution Uniformity (LQDU) and emitter

flow rate for each year are presented in Table 1. The pumpkin trial was seeded in the late spring each year. In order to determine the quantity of irrigation water applied, the flow rate of the trickle line had to be determined. The flow rate, measured at approximately 8 psi (pounds per square inch) operating pressure, decreased down the length of the trickle line from the head to the tail end. The LQDU, a measurement of water application uniformity, indicated that the uniformity of the trickle system used at this site was considered good to very good each year it was measured. This indicates that the water was applied uniformly over the trial area. The flow rate, measured at an operating pressure of 8 pounds per square inch (psi), was used to calculate the quantity of water applied at each irrigation time. Values for LQDU and emitter flow rate were not measured in 2005 but were assumed to be the same as the values measured in 2004.

The wetting characteristic moisture release curve data, generated using a model WP4 DewPoint PotentiaMeter, from soil samples collected representing the four sub-sample locations across the nine mulch strips indicated that the soil in the trial area was variable (Table 2). Field capacity (100% A.W.) for the 0-30 cm depth ranged from 0.1890 to 0.3654 g/g while permanent wilting point (0% A.W.) for the 0-30 cm depth ranged from 0.0767 to 0.0995 g/g for the years 2002-2005. Using these values, the estimated water potential for Water Treatment 1 (85% A.W.) and Water Treatment 2 (70% A.W.) were determined to range from 17-24 and 28-42 cb respectively (Table 2). In order to maintain soil available water above these levels, irrigation was initiated to maintain the soil water potential as indicated by the tensiometers at the 30 cm depth in the range of or below 20-30 cb for Water Treatment 1 (85% A.W.) and in the range of or below 30-40 cb for Water Treatment 2 (70% A.W.).

Tensiometer readings throughout the growing season for the pumpkin irrigation scheduling trial indicated that the targeted soil moisture tension for the two water application treatments was generally maintained throughout the growing season for the years during which the trial was conducted (Figure 13 and 14). The exception was in 2003 when growing conditions were hot and dry later in the growing season and the readings exceeded the targeted soil moisture tension for short periods. The shallow (0-30 cm) tensiometer readings increased as water was extracted by the pumpkin plants from the soil and then decreased as irrigation water was applied. Readings of the deep tensiometer placed at a depth of 50-60 cm in each tensiometer nest generally followed the same trend as the shallow tensiometer readings but with reduced amplitude in the fluctuations. The deep tensiometer readings also indicated that the soil moisture tension was maintained within the targeted levels lower in the rooting zone and that the proper quantity of irrigation water was applied.

The timing and quantity of irrigation water applied to the pumpkin varied among the years that the trial was conducted (Table 3). The highest quantity of water was applied in 2003 (W1 = 297 mm or 876 L/m row). The quantity of water applied in 2002 (W1 = 155 mm or 464 L/m row) was also high compared to 2004 (W1 = 88 mm or 264 L/m row) and 2005 (W1 = 44 mm or 133 L/m row). In 2002 and 2003 large quantities of irrigation water were applied to maintain soil water tension within the targeted levels due to below average precipitation (Figure 11: 2002 = 159 mm; 2003 = 130 mm) and higher than average temperatures during the growing season resulting in high potential evapotranspiration (ET) conditions (Figure 12). The warm growing season conditions in 2002 and 2003 resulted in high growing season potential ET (2002 = 715; 2003 = 726 mm). As a result pumpkin growth and yield for the irrigated treatments in 2002 and 2003 was good and the fruit matured (Figure 15) well before the first fall frost (2002 =

September 26; 2003 = September 30). In 2004 and 2005, limited irrigation water was required to maintain the soil water tension within the targeted levels due to the higher than normal precipitation (Figure 11: 2004 = 305 mm; 2005 = 391 mm) and below normal temperatures during the growing season resulting in low potential evapotranspiration (ET) conditions (Figure 12: 2004 = 569 mm; 2005 = 590 mm) compared to 2002 and 2003. As a result, in 2004 and 2005 the growth of the pumpkin plants lagged behind all season and the fruit did not reach full maturity (orange color change) by the first fall frost (2004 = September 30; 2005 = September 28).

Total water use for the growing season indicated that water use was of the order Water Treatment 1 > Water Treatment 2 > Dryland Treatment for all four years that the trial was conducted (Table 4). Water Treatment 1 used significantly more water than Water Treatment 2 and the Dryland Treatment in all years (Table 4). Water Treatment 2 only used significantly more water than the Dryland Treatment in the hot and dry years of 2002 and 2003. The higher than average temperature and lower than average precipitation in 2002 and 2003 resulted in high potential ET and thus high demand for irrigation applications in order to maintain the soil water potential at the specified levels for the given treatments (W1 = 20-30 cb; W2 = 30-40 cb). In the wetter and cooler years of 2004 and 2005 there were no significant differences in water use between Water Treatment 2 and the Dryland treatment. The lower than average temperature and higher than average precipitation in 2004 and 2005 resulted in low potential ET and thus low demand for irrigation applications in order to maintain the soil water potential at the specified levels for the given treatments. Thus, the low quantity of irrigation applied for Treatment 2, the higher water potential treatment, in 2004 and 2005 resulted in no significant difference in total water use from the Dryland Treatment.

Yield response of the pumpkin varied among the years the trial was conducted and appeared to be related to growing season conditions (Table 4). In 2002 and 2003, when growing conditions were generally warmer and drier than average, pumpkin yield increased as the quantity of water applied was increased. Water Treatment 1 produced the highest yield, however, it was not significantly greater than the yield produced by Water Treatment 2. Both Water Treatment 1 and 2 produced significantly greater pumpkin yield than the Dryland Treatment. Yield differences were due to pumpkin size but not the number of pumpkins produced. Pumpkins produced under Water Treatments 1 and 2 had a higher mean weight than for the Dryland treatment. The number of pumpkins produced for Water Treatments 1 and 2 were slightly higher than for the Dryland Treatment, however, the differences were not significant. The fruit size distribution indicated that in 2002 the Dryland Treatment pumpkin weight was fairly evenly distributed between the < 5 kg weight class and the 5-10 kg weight class (Figure 16). In 2003, the fruit size distribution indicated that for the Dryland Treatment a greater percentage of pumpkins were in the < 5 kg weight class compared to the 5-10 kg weight class. For Water Treatments 1 and 2 a greater percentage of pumpkins were in the 5-10 kg weight class than the < 5 kg and > 10 kg weight classes in both 2002 and 2003. Less than 11% of the pumpkins produced in 2002 and <3% of the pumpkins produced in 2003 were >10 kg in size. The Dryland treatment in 2002 did not produce pumpkins in the >10kg weight class. The addition of irrigation water in 2002 and 2003 increased yield by allowing the pumpkin fruit that was present to increase in size rather than producing more pumpkin fruit.

In 2004 and 2005, when growing conditions were cooler and wetter than average, pumpkin yields showed no response to the irrigation water applications (Table 4). Yields in 2004 were

low while the yields in 2005 were high with both years showing no significant yield differences due to the water treatments. As well, in both 2004 and 2005 the number of pumpkins produced per unit area, the mean pumpkin weight and the fruit size distribution also showed no significant differences among the water treatments. In 2004, a greater percentage of pumpkins were in the < 5 kg weight class than the 5-10 kg weight class (Figure 16). Less than 1% of the pumpkins produced were in the > 10 kg weight class. In 2005, a greater percentage of pumpkins produced were in the 5-10 kg weight class than the < 5 kg weight class. As well, more than 20% of the pumpkins produced were in the > 10 kg weight class, a higher percentage than was observed in the previous three years that the trial was conducted. The lack of yield response in both 2004 and 2005 to the addition of irrigation water was probably due to the cool growing conditions. As well, the cool wet growing conditions prevented the pumpkins that were produced from maturing properly, resulting in green pumpkins in both 2004 and 2005 (Figure 16), and provided ideal conditions for the onset of disease and fruit rot in 2004 (Figure 18). The high yield in 2005 would be considered a potential yield rather than a marketable yield since the majority of pumpkins that were produced did not mature but remained green late into the growing season.

Pumpkin yield increased as the water use increased in both 2002 and 2003 but showed no relationship to water use in 2004 and 2005 (Figure 19). By combining the data for 2002 and 2003, the years in which growing conditions were warmer and drier than average and which showed a response to irrigation application, a significant relationship between pumpkin yield and water use resulted (Figure 20). In 2002 and 2003, highest yield was produced for Water Treatment 1 (water use : 2002 = 322 mm and 2003 = 406 mm) which had the highest water use while the lowest yield was produced for the Dryland Treatment (water use: 2002 = 101 mm and 2003 = 143 mm) which had the lowest water use. Water Treatment 2 (water use : 2002 = 178 mm and 2003 = 310 mm) had yield and water use between Water Treatment 1 and the Dryland treatment. In 2004 and 2005, the cooler and wetter than average growing conditions resulted in a low demand for irrigation applications and thus there was no significant response of yield to total water use over the growing season.

Water use efficiency (kg pumpkin produced/mm water use) varied among the years and appeared to be related to growing conditions (Figure 21). In 2002 and 2003, where growing conditions favored a yield response to irrigation applications, water use efficiency decreased as the quantity of water applied was increased. Even though pumpkin yield was increased by the addition of irrigation water, the efficiency with which the water was used to produce dry matter decreased the greater the quantity of water applied. In 2004 and 2005, where there was a low demand for irrigation applications and no significant response of yield to total water use over the growing season, water use efficiency showed little response to the different water application treatments. The efficiency with which water is used to produce dry matter must be balanced with the availability of water for irrigation when deciding on the best use of the water supply.

It is very clear from these results that adequate heat is required for optimum pumpkin production. Without adequate heat there will be no response to irrigation water applications.

Table 1. Planting date, fertilizer application, LQDU and emitter flow rate for the pumpkin irrigation scheduling trial conducted from 2002-2005 at Outlook, Saskatchewan.

Year	Planting Date	Fertilizer Application (kg/ha)			LQDU[1] (%)	Emitter flow rate (L/hr)
		N	P_2O_5	K_2O		
2002	June 7	56	78	-	84	1.164
2003	May 30	45	60	100	95	0.878
2004	June 4	45	60	100	86	1.236
2005	June 6	-	100	100	-	-

[1] LQDU rating: >90% - excellent; 80-90% - good; 70-80% - fair; <70% - poor

Table 2. Wetting characteristic moisture release data for the 0-30 and 30-60 cm soil depths in the pumpkin irrigation scheduling trial area conducted from 2002-2005.

Year	Depth (cm)	Measured F.C.[1] (g/g)	Measured P.W.P.[2] (g/g)	Estimated Water Potential @ 85% A.W.[3] (cb)[4]	Estimated Water Potential @ 70% A.W. (cb)
2002	38746	0.189	0.0767	24	42
	30-60	0.2087	0.0771	21	36
2003	38746	0.3654	0.088	17	28
	30-60	0.3202	0.0911	22	36
2004	38746	0.3478	0.0995	20	31
	30-60	0.4928	0.0983	22	34
2005	38746	0.2278	0.0801	21	36
	30-60	0.2408	0.0823	18	36

[1] Field Capacity - drained upper limit of plant available water in soil (-0.01 MPa).
[2] Permanent Wilting Point - lower limit of plant available water in soil (-1.5 MPa).
[3] Available Water = FC - PWP, where FC = 100% AW and PWP = 0% AW
[4] centibar (cb) = 0.01 bar or 0.001 megapascals (MPa)

Table 3. Irrigation water application, precipitation, soil profile moisture change and total water use for trickle irrigated Spirit pumpkin (2002-2005).						
Year	Water Treatment	Irrigation Application		Precipitation (mm)	Soil Profile Moisture Change (Spring - Fall)	Total Water Use[2] (mm)
		L/m row	mm[1]			
2002	W1	464	155	86	4.32	245
	W2	169	56	86	8.04	150
	Dry	0	0	86	14.98	101
2003	W1	876	297	102	6.35	405
	W2	609	203	102	5.09	310
	Dry	0	0	102	40.26	142
2004	W1	264	88	274	-77.37	285
	W2	79	26	274	-89.65	211
	Dry	0	0	274	-89.24	185
2005	W1	133	44	226	1.68	272
	W2	24	8	226	0.72	235
	Dry	0	0	226	2.57	229

[1] Water Application (mm) =
application rate/emitter (L/hr) x application time (hr) x area/emitter (m^2) x 1 mm/L/m^2
(area/emitter = distance between emitters (m) x distance between mulch rows (m))

[2] Total Water Use = Irrigation + Precipitation + Soil Profile Moisture Change (Spring-Fall)

Table 4. Effect of water treatment on yield, number of pumpkins, mean weight and total water use for trickle irrigated Spirit pumpkin (2002-2005).					
Year	Water Treatment	Yield (kg/m double row)	Pumpkin Quantity (#/m double row)	Mean Pumpkin Weight (kg)	Total Water Use (mm)
2002	W1	23.13	3.4	6.79	245
	W2	19.53	3.1	6.41	150
	Dry	13.55	2.6	5.17	101
	LSD (0.05)	13.7	NS[1]	12.6	8
	CV (%)	4.07	13.7	1.23	21
2003	W1	22.06	3.9	5.56	405
	W2	19.83	3.5	5.71	310
	Dry	13.74	3.2	4.52	142
	LSD (0.05)	5.03	NS	0.81	35
	CV (%)	27.1	24.1	15.4	12.3
2004	W1	8.55	2	4.38	285
	W2	8.96	2	4.6	211
	Dry	8.27	1.8	4.49	185
	LSD (0.05)	NS[1]	NS	NS	69
	CV (%)	24.5	17.4	26.2	30.3
2005	W1	26.95	3.8	7.13	272
	W2	27.11	3.7	7.31	235
	Dry	25.35	3.6	7.09	229
	LSD (0.05)	NS[1]	NS	NS	17
	CV (%)	10.1	6.9	9.6	7

[1] not significant

Figure 1. Application of IRT plastic mulch and trickle tape for pumpkin trial.

Figure 2. Hand seeding pumpkin through IRT plastic mulch with the aid of a water wheel planter.

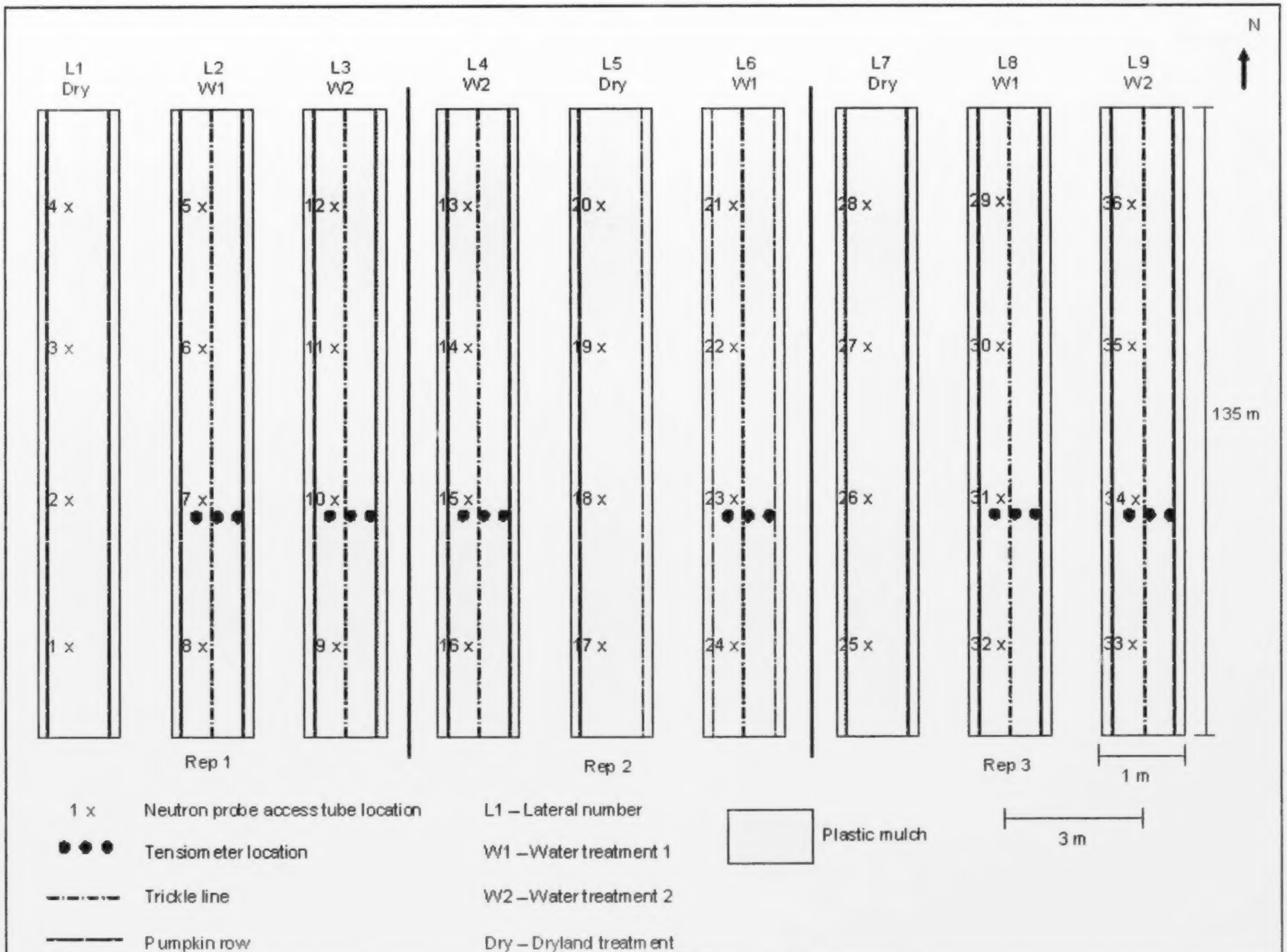


Figure 3. Pumpkin irrigation scheduling trial field layout (2002-2005).

Figure 4. Measurement of trickle tape emitter flow rate.

Figure 5. Soil moisture measurement with the neutron probe moisture meter.

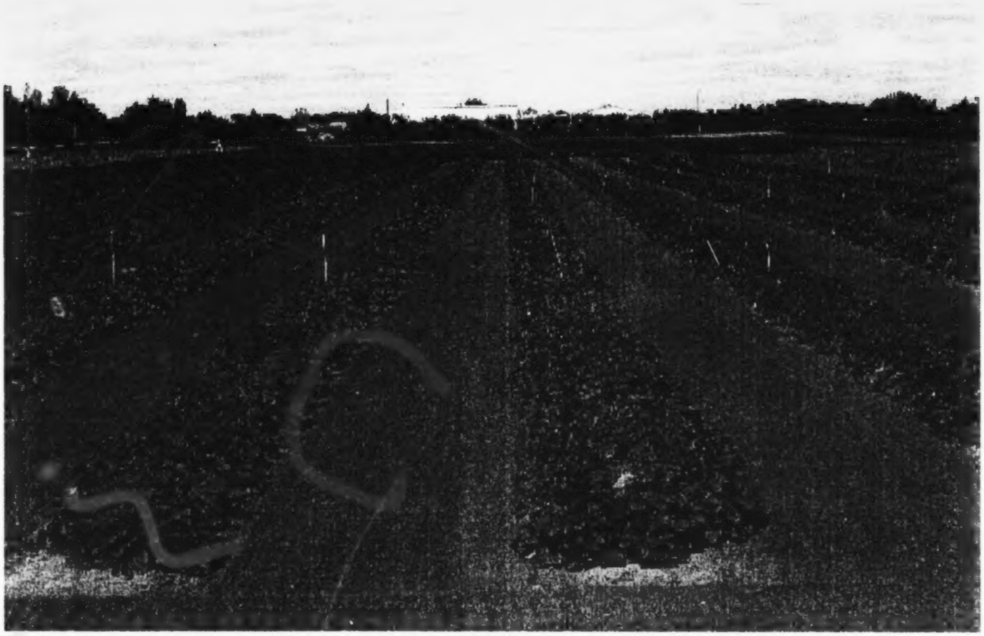


Figure 6. Pumpkin treatment rows with flags marking sub-sample points.

Figure 7. Surface soil (0-15 cm) moisture measurement with the TDR 300 soil moisture instrument.

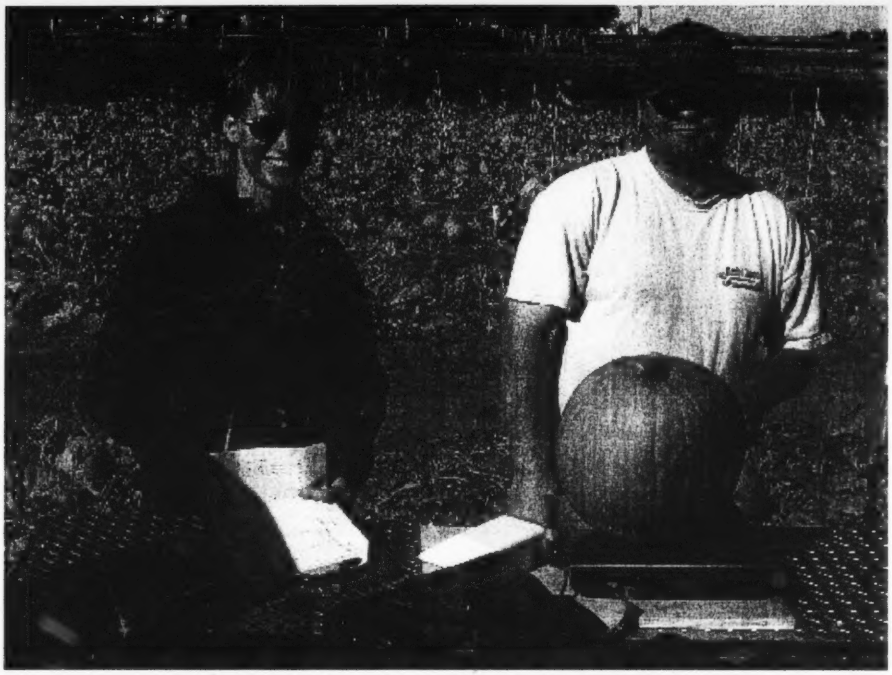


Figure 8. Recording weight of pumpkins in the field at harvest.

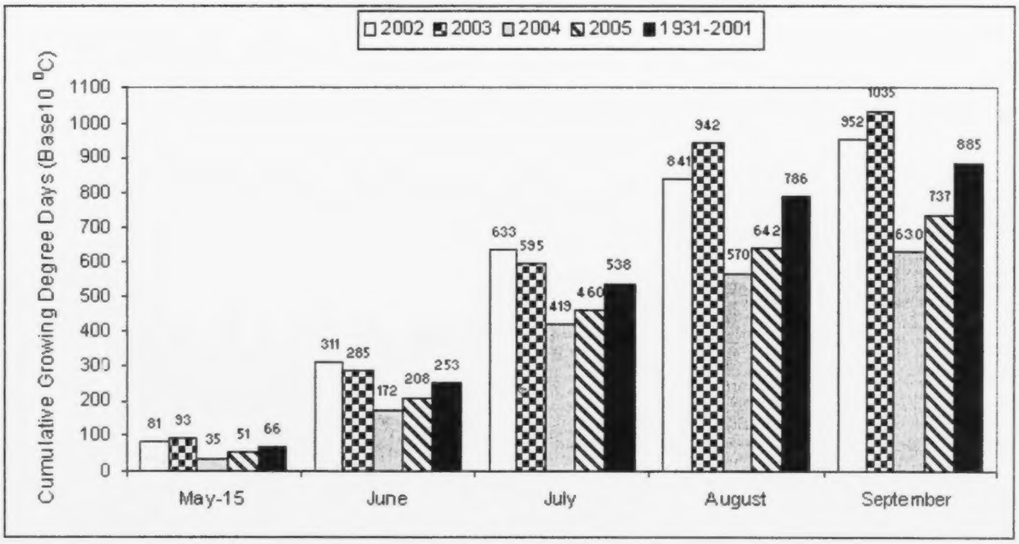


Figure 9. Cumulative Growing Degree Days (Base 10 °C) at Outlook, Saskatchewan for the period 2002 to 2005 compared to the long term average 1931-2001.

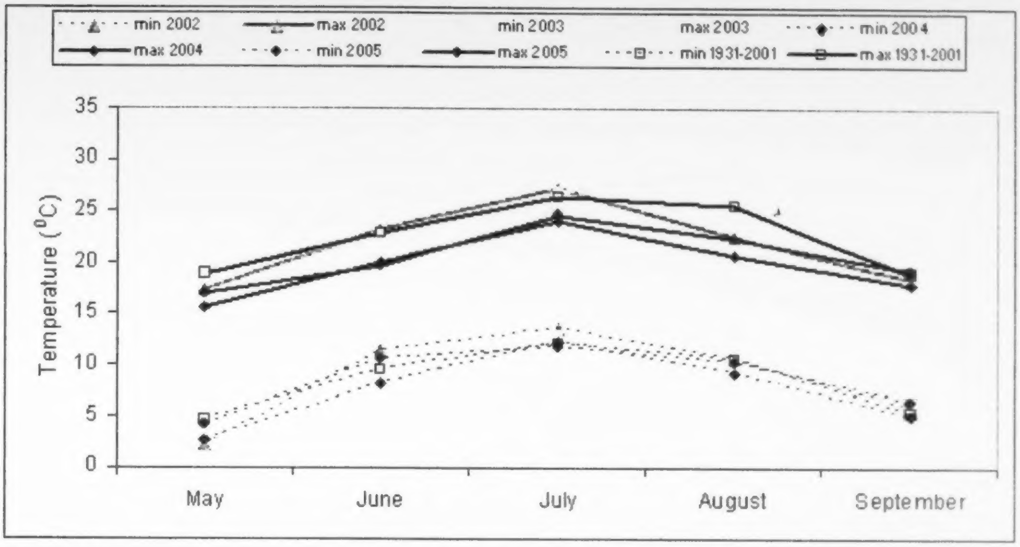


Figure 10. Minimum and maximum monthly temperatures at Outlook, Saskatchewan for the period 2002 to 2005 compared to the long term average 1931-2001.

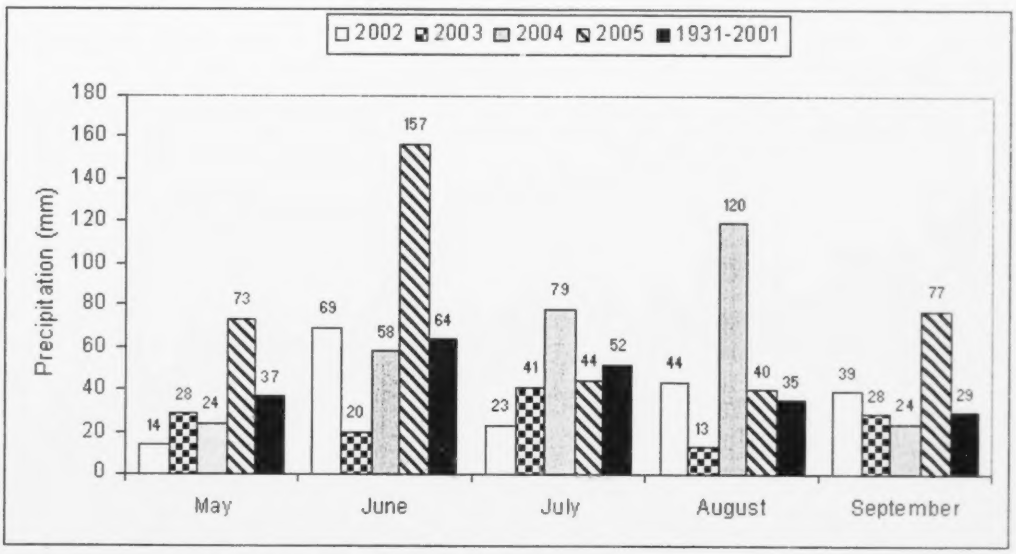


Figure 11. Precipitation at Outlook, Saskatchewan for the period 2002 to 2005 compared to the long term average 1931-2001.

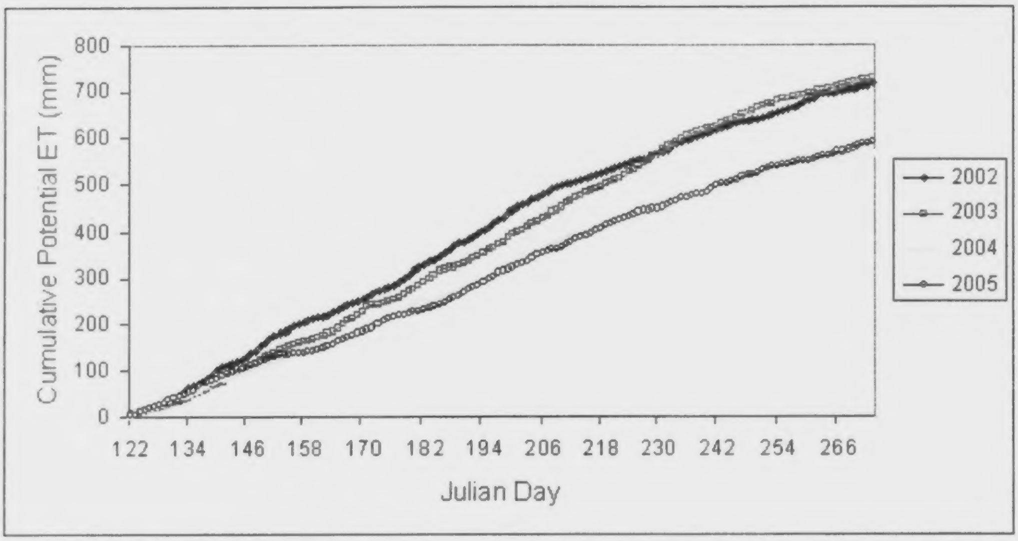


Figure 12. Penman-Monteith cumulative potential evapotranspiration (mm) for the 2002-2005 growing seasons (May 1 - September 30) at Outlook, Saskatchewan. (Crop evapotranspiration - Guidelines for computing crop water requirements - FAO Irrigation and Drainage Paper 56).

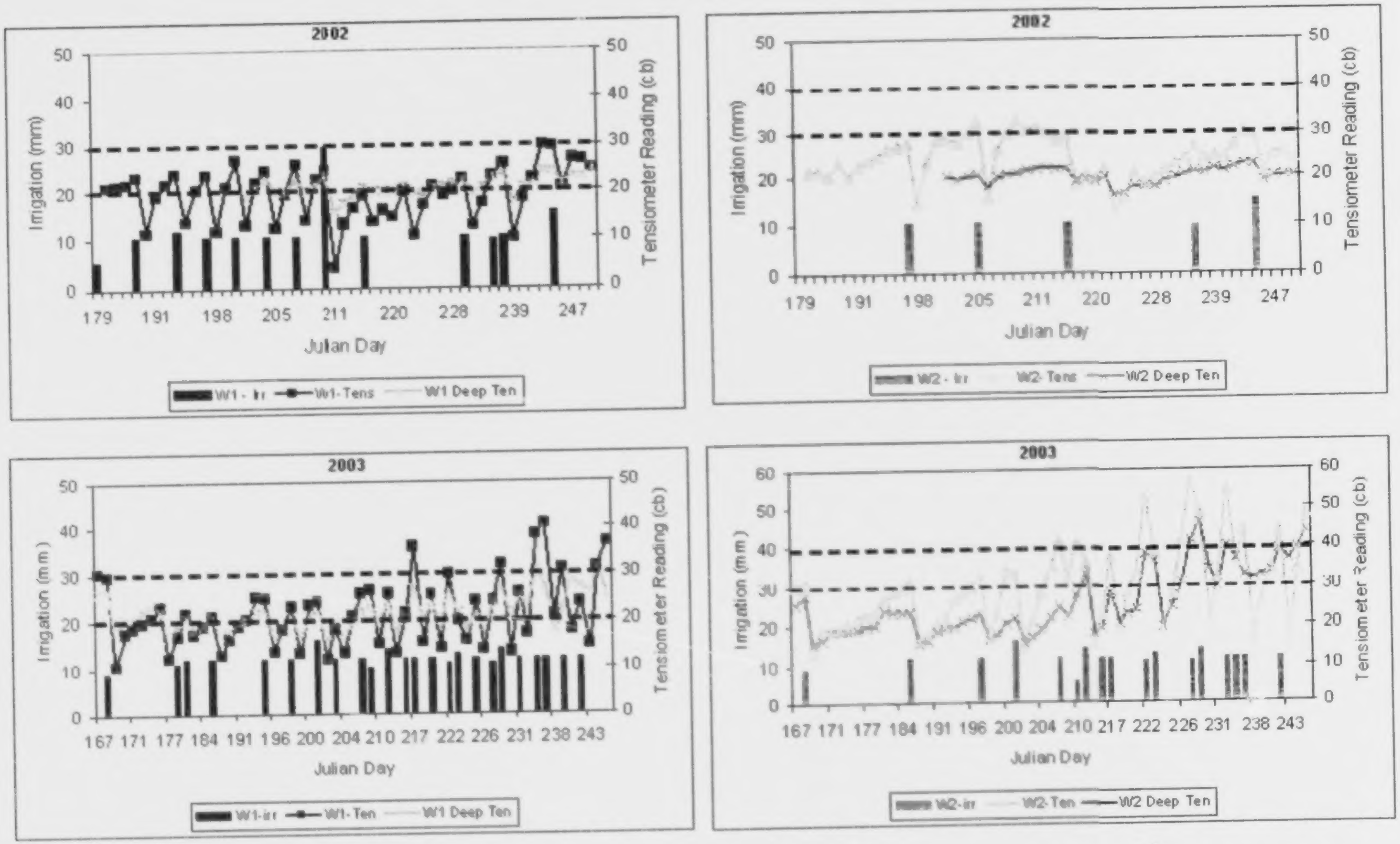


Figure 13. Water Treatment 1 and 2 tensiometer readings and irrigation applications for the pumpkin trickle irrigation scheduling trial for the years 2002 and 2003.

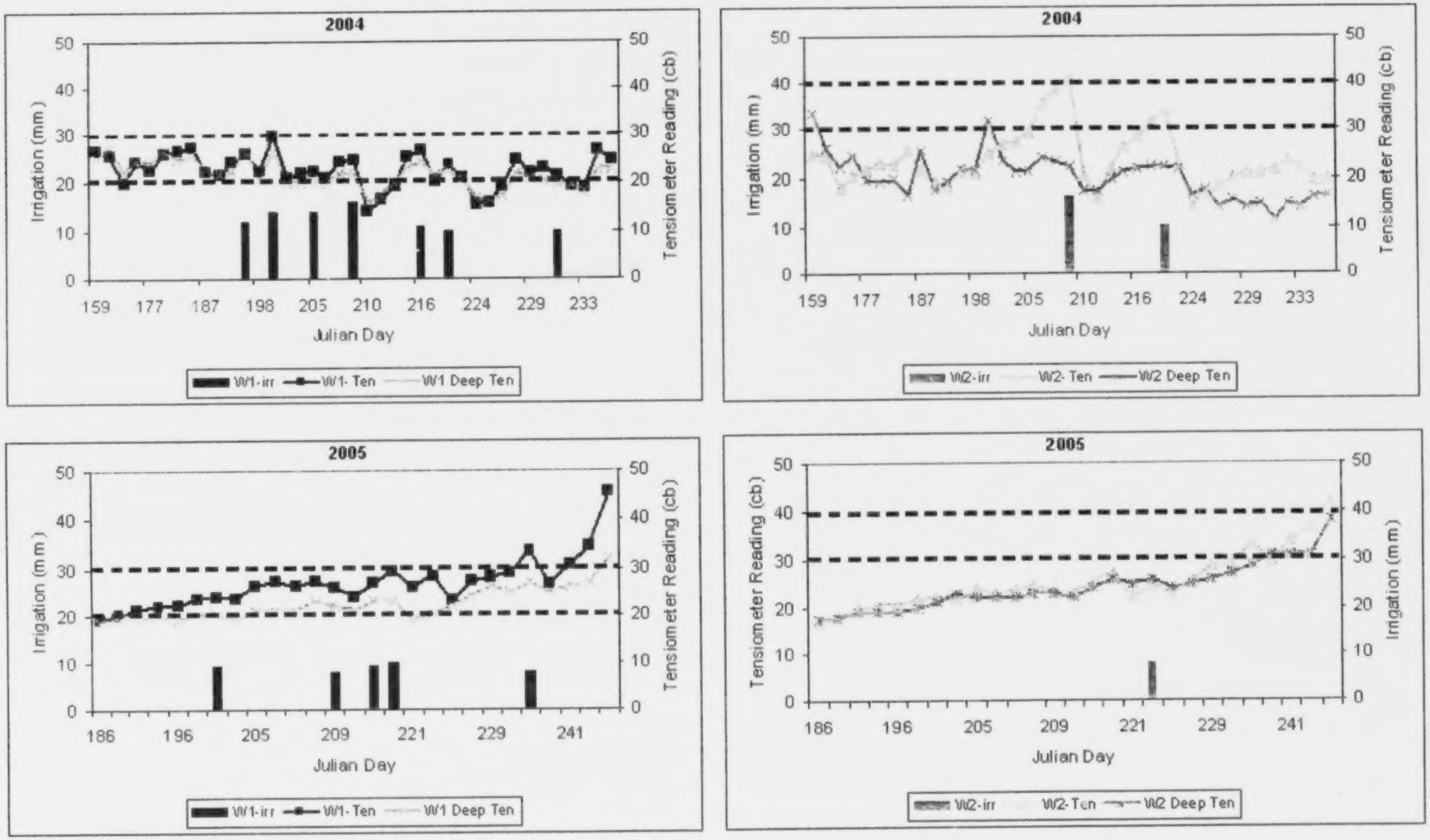


Figure 14. Water Treatment 1 and 2 tensiometer readings and irrigation applications for the pumpkin trickle irrigation scheduling trial for the years 2004 and 2005.

Figure 15. Orange colour of mature pumpkin produced in 2002 and 2003.

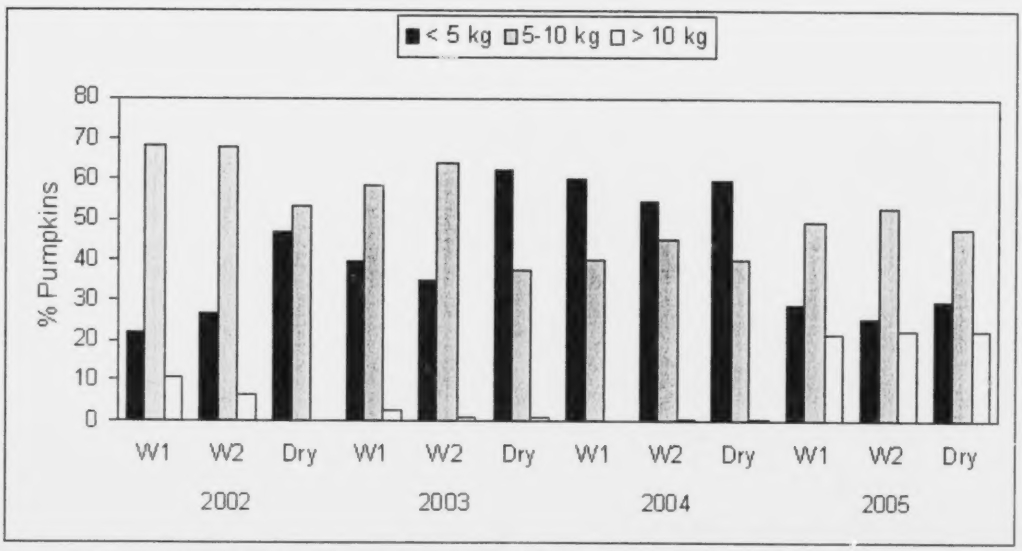


Figure 16. Water treatment effect on fruit size distribution of trickle irrigated Spirit pumpkin (2002-2005).

Figure 17. Green pumpkins produced in 2005.

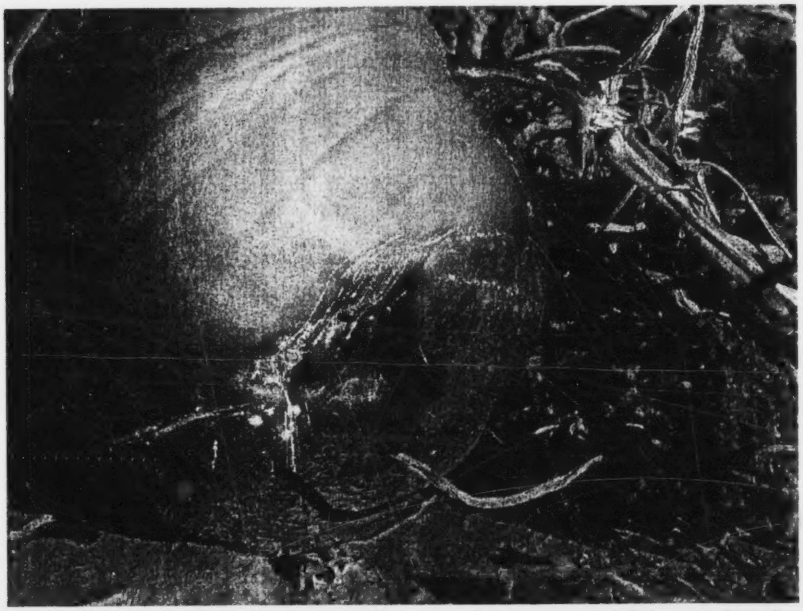


Figure 18. Fruit rot of pumpkin in the field a result of the cool and wet growing season conditions in 2004.

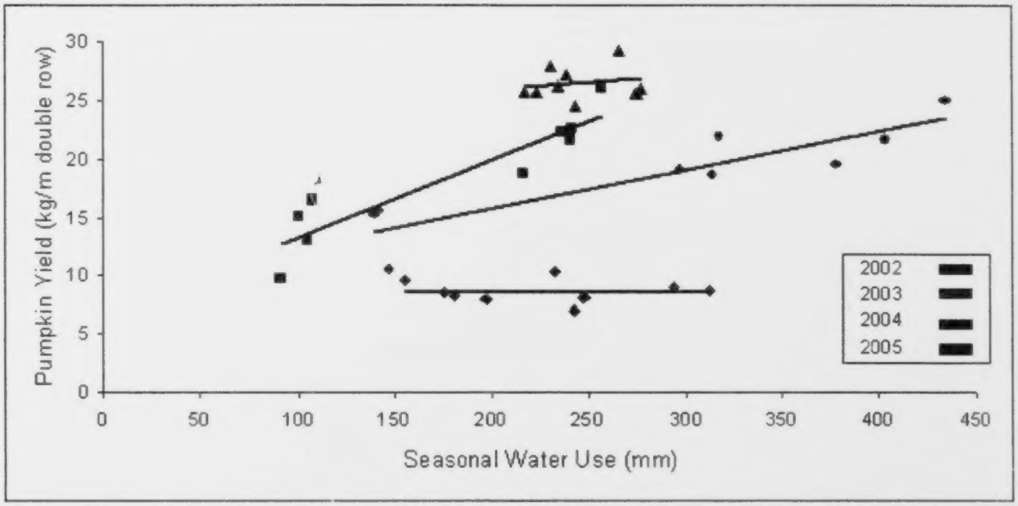


Figure 19. Relationship between yield and water use for trickle irrigated Spirit pumpkin (2002-2005).

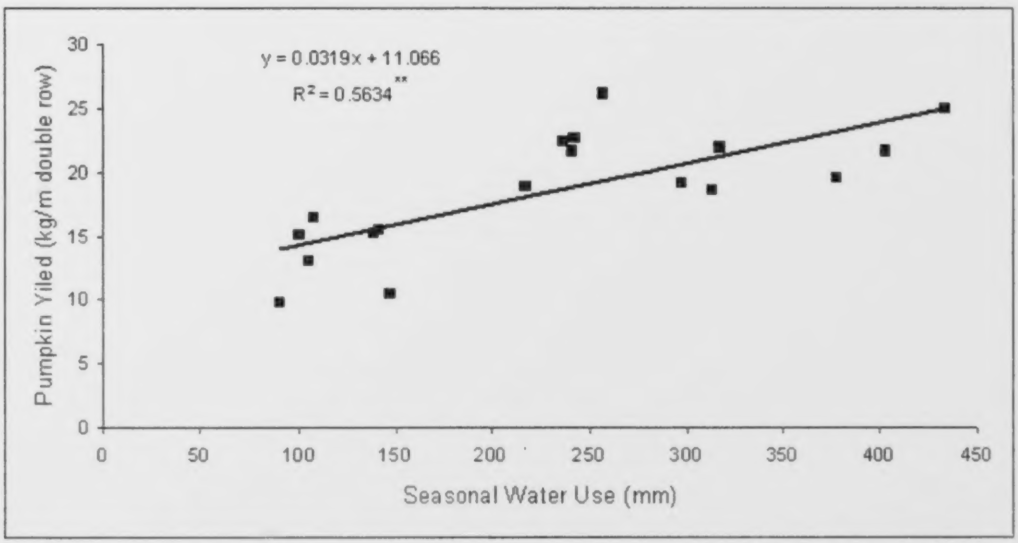


Figure 20. Relationship between yield and water use for trickle irrigated Spirit pumpkin combined for the years 2002 and 2003.

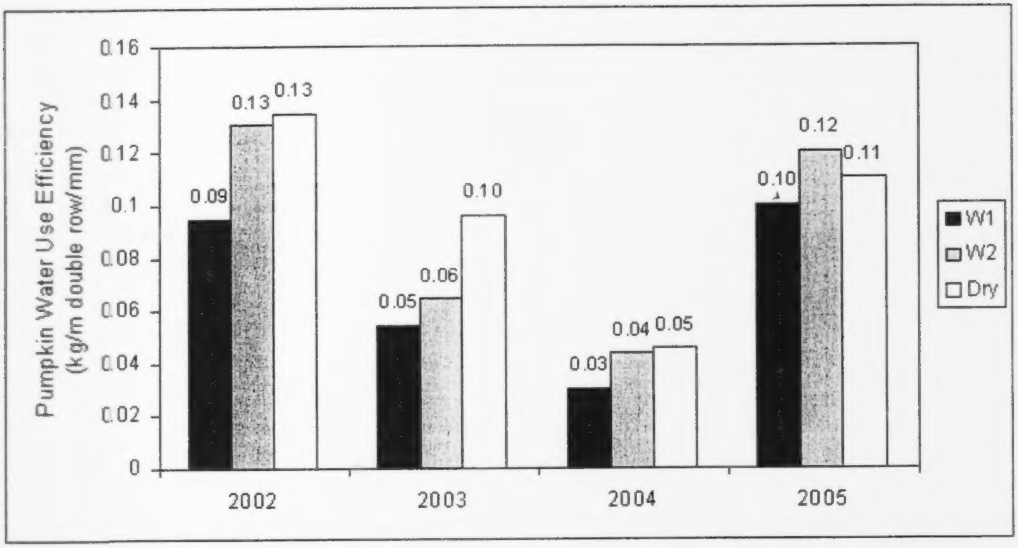


Figure 21. Water treatment effect on water use efficiency of trickle irrigated Spirit pumpkin (2002-2005).

Cabbage and Celery Storage Demonstration

Barry Vestre, Terry Hogg and Jazeem Wahab

Summary

In 2005, the Canada-Saskatchewan Irrigation Diversification Centre (CSIDC) completed a cabbage storage demonstration and an observational celery storage demonstration. This was the third of a three year demonstration. Three cultivars of cabbage (Cecile, Bravo, and Lennox) grown in CSIDC fields were evaluated under three separate types of storage. A filacel cooler (FC), an evaporative cooler (EC) with an humidifier, and an insulated storage with no artificial cooling (NAC) or humidification. All storages are located in the Vegetable Storage and Handling Facility at the CSIDC.

The varieties of cabbage used in this study were recommended by producers and industry. The cabbage was grown to maturity and harvested. Yields were recorded, and sub-samples of each variety were placed in the coolers. Cabbage samples were removed from storage after 60, 120, and 180 days.

The celery storage demonstration was observational only. A small area of celery was produced with the majority sold at harvest. A portion of the crop was placed in the filacel cooler and monitored to determine storability. The celery remained in a marketable condition for approximately three to four weeks after harvest, greatly extending the marketing period.

Background

As with many other vegetables, the province imports over 90% of its cabbage requirement. Saskatchewan producers can and do produce high yields of quality fresh market and storage cabbage. One key factor limiting expansion is the lack of proper storage. Many of the current producer's storages are basic cold cellar facilities that cannot keep the cabbages in a marketable condition past early December. The demand for fresh market and processing cabbage continues throughout the winter with increased prices over those in the fall. To capture a portion of this market, producers need to be able to store their cabbage longer into the winter while considering the additional costs associated with this storage.

Objective

To demonstrate storage techniques for cabbage and other selected vegetables that will allow extension of the marketing period, and to determine the costs and returns for three storage techniques.

Cabbage Storage

Study Description

The cabbage for the storage trials were produced in Field 1 in 2002 and 2003 and in Field 2 in 2004 at CSIDC. Fertilizer was applied according to soil test recommendations. Treflan was applied at recommended rates and incorporated for weed control.

Lennox, Cecile, and Bravo cultivars were seeded in the greenhouse in late April in 162 seedling trays. The cabbages were transplanted in the field mid-May with a water wheel transplanter. Row spacing was 60cm and plant spacing was 45cm. A two metre driveway was left every 12 rows of cabbage to accommodate spraying operations. Lorsban was applied to control root maggots. Alternate applications of Ripcord, Decis, and Sevin were applied to control flea beetles. Irrigation was provided with a low pressure centre pivot. Soil moisture was monito

red with tensiometers.

Harvest occurred as each variety matured. Cecile and Bravo varieties were typically one month earlier than Lennox. Harvested yields were recorded for each variety. Size and weights of 12 randomly selected cabbage heads of each variety were collected and disease conditions noted. An additional 36 heads of each variety were sized, weighed, and placed in (i) a filacel cooler/storage, (ii) an evaporative cooler with an humidifier, and (iii) a basic cold storage with no artificial cooling or humidification.

A filacel cooler is a special cooling and humidification unit designed to maintain temperatures at or near 0° C and humidity at or near 100% without freezing. These conditions are required for many of the storage type vegetables. An evaporative cooler can maintain temperatures near 3° C (the unit will freeze up at lower temperatures) but also dehumidifies the air. A humidifier was placed in this cooler to counteract the dehumidification of the cooling unit.

After 60, 120, and 180 days, 12 cabbages of each variety were removed from the coolers. Discolored and diseased outer leaves were removed as required and the cabbage was weighed to determine storage losses and the net marketable weight.

Temperature and relative humidity (RH) data from the filacel and evaporative cooler were collected using "Hobo" temperature and RH data loggers. The filacel averaged 1.2°C and 98.5% R.H. The evaporative cooler averaged 3.6 °C and 95% R.H. The storage with no artificial cooling was maintained at 5°C.

Results

Harvested yields of cabbage were high for each of the three years. The average yields were 79 t/ha, 78 t/ha, and 71 t/ha for Lennox, Bravo, and Cecile respectively (Table 1).

Storage losses varied between varieties, type of cooler, and year (Table 2). Lennox, which is more suited to storage, stored very well in both the FC and EC coolers and reasonably well in the NAC cooler in all three years. Bravo and Cecile were more unpredictable as they stored well in 2002 but not in 2003 and 2004. This is due in part to the growing conditions in 2003 and 2004. In 2003, growing conditions were excellent resulting in the Bravo and Cecile maturing in mid-August. The cabbage were put into storage much earlier than normal when outside temperatures were warm resulting in significant storage losses. After 120 days, there was 100% storage loss of Bravo and Cecile in all cooler types. In 2004, growing and harvest conditions were wet resulting in disease development in the field. Disease was carried into storage resulting in 100% loss after 120 days.

The results show that Lennox will store better than Cecile or Bravo in each of the three cooler types. The filacel or evaporative coolers will have similar storage losses throughout the storage period. Cecile and Bravo cabbage stored with no artificial cooling or humidification will deteriorate very quickly, especially if the harvest is early or harvest conditions are not favorable for proper storage.

Since the Cecile and Bravo varieties did not store well in each of the coolers, Lennox will be used to determine the economic viability of storing cabbage for the final report.

Economics

NOTE: The information provided below is a guideline only. Individual crop, marketing, building plans, and costs should be developed by each producer BEFORE beginning their venture.

To determine the economic viability of producing and storing cabbage on a small but commercial scale, we have developed case studies for each storage type utilizing data collected from this and past demonstrations. Out sourcing of information was done where required. The following assumptions were made for each cooler type.

A) Storage #1- No Artificial Cooling (NAC)
- The storage will have a capacity of approximately 350 T (or 10 acres) c/w a load out area. A fan and outside air will be used for cooling and a Climacell tank for humidification.
- A portion of the cabbage will be sold into the fresh market, with the majority sold for processing. The marketing period will be from mid-September to mid-December.
- The cabbage will be hand harvested, stored in plastic pallet bins, packed and shipped.

B) Storage #2- Filacel Storage
- The storage will have a capacity of approximately 350 T (or 10 acres) c/w a load out area. A filacel cooling unit will be used for cooling and humidification.
- A portion of the cabbage will be sold into the fresh market, with the majority sold for processing. The marketing period will be from mid-September to March.
- The cabbage will be hand harvested, stored in plastic pallet bins, packed and shipped.

C) Storage #3- Evaporative Cooler
- The storage will have a capacity of approximately 350 T (or 10 acres) c/w a load out area. An evaporative cooling system will be used for cooling and a climacell tank for humidification.
- A portion of the cabbage will be sold into the fresh market with the majority sold for processing. The marketing period will be from mid-September to March.
- The cabbage will be hand harvested, stored in plastic pallet bins, packed and shipped.

The estimated capital investments are $385,000 for the NAC; $415,000 for the EC; and $455,000 for the filacel (Appendix A). It must be emphasized that these are estimates only and that the actual costs may be lower or higher depending on each individual situation. The physical structure and handling equipment for all storages is identical with the artificial cooling equipment added to the EC and the filacel.

The estimated cost and returns for each storage type are presented in Appendix A. Gross returns were calculated using historic prices and marketing the volume of cabbage evenly through the storage period. The gross return for the filacel and EC storages are slightly higher than the NAC due to the increased prices received during the winter months. However, with the added operating and capital costs of the refrigeration equipment, the net returns are slightly lower than the NAC.

Celery Storage

Study Description

Celery was produced on Field 1 in 2002 and 2003 and on Field 2 in 2004. The fields were fertilized according to soil test recommendations. The cultivar Utah 52-70 was seeded in the greenhouse in late March and transplanted in the field in late May. A water wheel transplanter was used to transplant the celery. Weed control consisted of hand roguing and roto-tilling. Soil moisture was maintained above 50% field capacity with a low pressure centre pivot and monitored with tensiometers. Harvest was completed in late September and a small sample placed in the filacel cooler and visually rated for six weeks for marketability.

Results

The celery stored well in the filacel cooler for two to three weeks.Wholesale buyers were impressed with the quality of the fresh and stored celery resulting in the entire production being marketed. Yields and prices were similar to previous trials conducted at CSIDC with projected gross returns of $10,000/ac and projected net returns of $1500/ac.

Conclusion

The production and storage of cabbage in Saskatchewan could be a viable alternative high value crop in Saskatchewan's irrigated areas. Based on the data collected from this demonstration, as well as the information collected from other sources, net returns per acre can be as high as $2000, with or without refrigerated storage. To achieve this level of return, producers must educate themselves on all aspects of cabbage production. An holistic approach involving agronomics, storage, and marketing are all required to ensure the venture is successful.

The production and storage of celery could also be a viable alternative high value crop. The observational trial showed that celery will store well in a filacel cooler for two to three weeks after harvest, thus increasing the marketing period. This provides producers some flexibility in their marketing plans. The economic viability of constructing and operating a filacel storage for celery only may be questionable as the production and marketing season is still quite short resulting in a high cost per unit of storage. The production and storage of celery may fit better in a marketing package that includes production of other vegetable crops that would compliment the use of a filacel storage.

Table 1. Yield estimates for cabbage cultivars grown under irrigation: 2002 - 2004

Variety	Estimated yield (t/ha)			
	2002	2003	2003	Average
Lennox	62	98	78	78
Bravo	66	88	81	78
Cecile	55	73	85	71

Table 2. Storage losses of cabbage cultivars under different storage environments and storage durations

Variety	Filacel			Evaporative Cooler			No Artificial Cooling		
2004									
	60 Days	120 Days	180 Days	60 Days	120 Days	180 Days	60 Days	120 Days	180 Days
Lennox	13	20	100	13	35	100	17	31	100
Bravo	11	19	100	11	24	100	100	100	100
Cecile	14	20	100	10	24	100	25	100	100
2003									
Variety	Filacel			Evaporative Cooler			No Artificial Cooling		
	60 Days	120 Days	180 Days	60 Days	120 Days	180 Days	60 Days	120 Days	180 Days
Lennox	13	21	22	14	34	34	32	36	39
Bravo	20	100	100	9	100	100	100	100	100
Cecile	17	100	100	21	100	100	100	100	100
2002									
Variety	Filacel			Evaporative Cooler			No Artificial Cooling		
	60 Days	120 Days	180 Days	60 Days	120 Days	180 Days	60 Days	120 Days	180 Days
Lennox	13	15	16	15	23	19	19	25	29
Bravo	17	25	23	19	26	27	26	35	100
Cecile	17	21	21	20	31	29	33	39	100

References

"Demonstration of Improved Vegetable Techniques for Saskatchewan"- Canada-Saskatchewan Irrigation Diversification Centre.

"Planning for Profit- Storage Cabbage"- British Columbia Dep. of Agriculture
"Irrigation Economics and Agronomics for Saskatchewan"- Irrigation Crop Diversification Corporation

Technical and cost information for storages provided by Kevin McCormick of Outlook Refrigeration and Air Conditioning, Outlook Saskatchewan.

Produce marketed and for pricing information provided by Oliver Green of Broderick Garden Centre, Outlook, Saskatchewan.

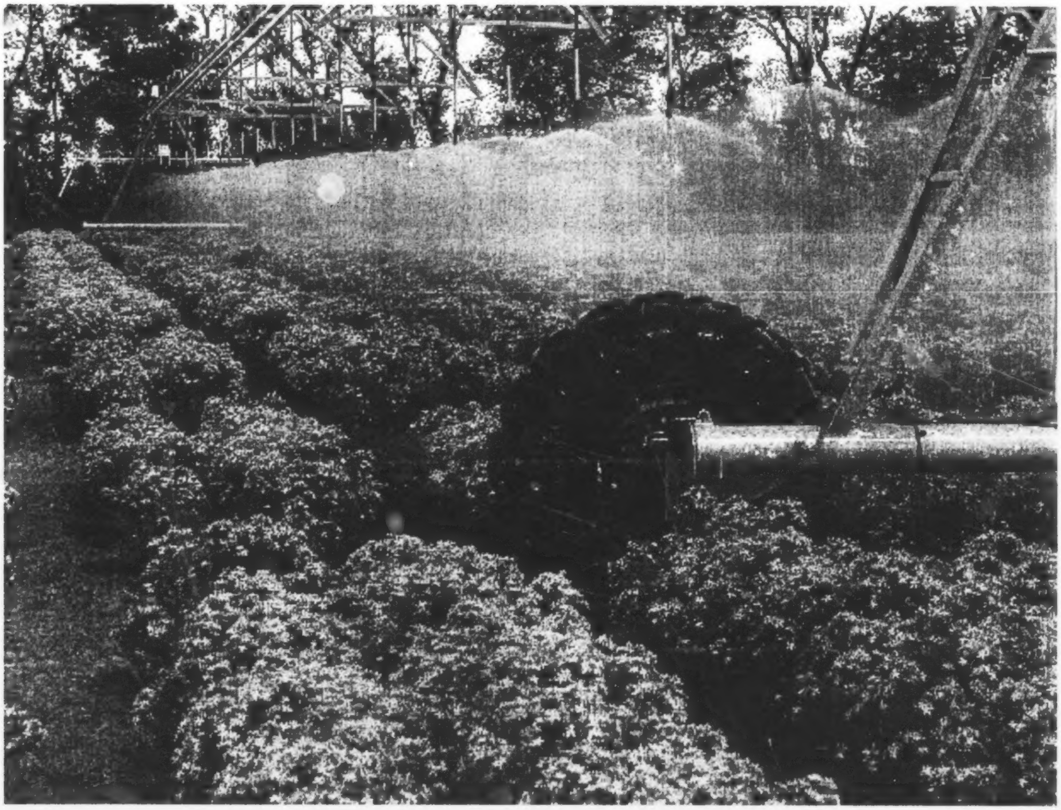
LENNOX CABBAGE- COST AND RETURN ANALYSIS-No Artificial Cooling (10 Acres)							
	Revenue					CAPITAL INVESTMENT REQUIRED	
	September	October	November	December	Total		INVESTMENT
Harvested Product (lbs)	50,000	230,000	230,000	230,000	740,000	LAND	$5,000
% Storage Loss	10	22	22	30		BUILDING	$200,000
Net Marketed Product	45,000	179,400	179,400	179,400		VENTILATION AND COOLING	$10,000
Price ($/lb)	$0.20	$.12	$0.15	$0.15		EQUIPMENT	
Gross Return	$9,000.00	$21,528.00	$26,910.00	$24,150.00	**$93,072.00**	FIELD	$50,000
	Expenses					HANDLING	$30,000
Cash Costs	$/ac		Expenses (10ac)			BINS	$70,000
Seed and Transplants	$200		$2000			IRRIGATION	$20,000
Fertilizer	$100		$1000			TOTAL CAPITAL INVESTMENT	**$385,000**
Pest Control	$100		$1000				
Irrigation	$40		$400				
Utilities Storage	$100		$1000				
Fuel	$100		$1000				
Repair	$80		$800				
Packaging	$1,100		$11,000				
Marketing	$300		$3000				
Freight and Handling	$600		$6000				
Farm Overhead	$80		$800				
Op. Interest	$50		$500				
Miscellaneous	$250		$2500				
Refrigeration and Electrical	$0.00		$0.00				
Total Cash Cost		$3,100			$31,000		
Labour Cost	$2500	$2,500			$25,000		
Non-Cash Cost							
Land	$40		$400				
Farm Equip & Buildings	$30		$300				
Specialized Equipment	$350		$3500				
Irrigation System	$45		$450				
Total Non-Cash		$465			$4,650		
Total Cost		$6,065			**$60,650**		
			NET RETURN ON 10 ACRES		**$20,938**		

LENNOX CABBAGE- COST AND RETURN ANALYSIS- EVAPORATIVE COOLER (10 Acres)								
	Revenue							
	September	October	November	December	January	February	March	**Total**
Harvested Product (lbs)	50,000	120,000	120,000	120,000	120,000	110,000	100,000	740,000
% Storage Loss	10	22	22	30	30	30	30	
Net Marketed Product	45,000	93600	93,600	84,000	84,000	77,000	70,000	
Price ($/lb)	$0.20	$.12	$0.15	$0.15	$0.20	$.20	$.20	
Gross Return	$9,000.00	$11,232.00	$14,040.00	$12,600.00	$16,800.00	$15,400.00	$14,000.00	**$93,072.00**
Expenses								
Cash Costs	$/ac		Expenses (10ac)					
Seed and Transplants	$200		$2000					
Fertilizer	$100		$1000					
Pest Control	$100		$1000					
Irrigation	$40		$400					
Utilities Storage	$100		$1000					
Fuel	$100		$1000					
Repair	$80		$800					
Packaging	$1,100		$11,000					
Marketing	$300		$3000					
Freight and Handling	$600		$6000					
Farm Overhead	$80		$800					
Op. Interest	$50		$500					
Miscellaneous	$250		$2500					
Refrigeration and Electrical	$1500		$15,000					
Total Cash Cost		$4600						$46,000
Labour Cost	$2500	$2500						$25,000
Non-Cash Cost								
Land	$40		$400					
Farm Equip.& Buildings	$30		$300					
Specialized Equipment	$350		$3500					
Irrigation System	$45		$450					
Total Non-Cash		$465						$4650
Total Cost		$7,565						**$75,650**
			NET RETURN ON 10 ACRES					**$17,422**

CAPITAL INVESTMENT REQUIRED	
	INVESTMENT
LAND	$5,000
BUILDING	$200,000
VENTILATION AND COOLING	$40,000
EQUIPMENT	
FIELD	$50,000
HANDLING	$30,000
BINS	$70,000
IRRIGATION	$20,000
TOTAL CAPITAL INVESTMENT	**$415,000**

LENNOX CABBAGE- COST AND RETURN ANALYSIS- Filacell COOLER (10 Acres)										
	Revenue								CAPITAL INVESTMENT REQUIRED	
	September	October	November	December	January	February	March	Total		INVESTMENT
Harvested Product (lbs)	50,000	120,000	120,000	120,000	120,000	110,000	100,000	740,000	LAND	$5,000
% Storage Loss	0.10	.22	0.22	0.30	0.30	.30	.3		BUILDING	$200,000
Net Marketed Product	45,000	93600	93,600	84,000	84,000	77,000	70,000		VENTILATION AND COOLING	$80,000
Price ($/lb)	$0.20	$.12	$0.15	$0.15	$0.20	$.20	$.20		EQUIPMENT	
Gross Return	$9,000.00	$11,232.00	$14,040.00	$12,600.00	$16,800.00	$15,400.00	$14,000.00	$93,072.00	FIELD	$50,000
Expenses									HANDLING	$30,000
Cash Costs	$/ac		Expenses (10ac)						BINS	$70,000
Seed and Transplants	$200		$2000						IRRIGATION	$20,000
Fertilizer	$100		$1000						TOTAL CAPITAL INVESTMENT	$455,000
Pest Control	$100		$1000							
Irrigation	$40		$400							
Utilities Storage	$100		$1000							
Fuel	$100		$1000							
Repair	$80		$800							
Packaging	$1,100		$11,000							
Marketing	$300		$3000							
Freight and Handling	$600		$6000							
Farm Overhead	$80		$800							
Op. Interest	$50		$500							
Miscellaneous	$250		$2500							
Refrigeration and Electrical	$1500		$15,000							
Total Cash Cost		$4600						$46,000		
Labour Cost	$2500	$2500						$25,000		
Non-Cash Cost										
Land	$40		$400							
Farm Equip.& Buildings	$30		$300							
Specialized Equipment	$500		$5000							
Irrigation System	$45		$450							
Total Non-Cash		$615						$6150		
Total Cost		$7715						$77,150		
			NET RETURN ON 10 ACRES					$15,922		

Develop Cost-Effective Agronomic Practices for Large Scale Production of St. John's Wort in Saskatchewan



Jazeem Wahab and Greg Larson

Project Background

Increasing health care costs, and individuals taking more responsibility for their own health, has lead consumers to seek alternate approaches to treat and prevent diseases. Consequently, natural products (nutraceuticals, functional foods, and dermaceuticals) represent one of the most rapidly expanding industries in the developed countries. In 1998, the global sales of nutraceuticals and functional foods was estimated at $71 billion (US) and is projected to reach $500 billion (US) by 2010 (Nutrition Business Journal, 1998). In the USA, the total nutraceutical and functional food sales was estimated to be $25.8 billion in 1998 and significant growth has been projected for the next three years (Nutrition Business Journal, 1998). The Canadian industry is believed to be in excess of $1.0 billion (Nutrition Business Journal, 1999). To meet the demand of this growing industry, the medicinal and aromatic plant production and processing sectors are growing fast in Saskatchewan. Effective agronomic practices are essential to consistently produce superior yields of high quality herbs. Agronomic research for commercially important herbs were carried out at the Canada-Saskatchewan Irrigation Diversification Centre in Outlook.

The Canada-Saskatchewan Irrigation Diversification Centre (CSIDC) with funding from the Canada-Saskatchewan Agri-Food Innovation Fund (AFIF) conducted research to develop cost-effective agronomic practices for commercial scale production of promising medicinal herbs such as *Echinacea angustifolia*, milk thistle, stinging nettle, feverfew, and St. John's Wort. Focus of CSIDC's herb research include:

- Evaluation of the adaptability of promising medicinal and culinary herbs for Saskatchewan conditions.
- Development of management practices for mechanized commercial production.
- Development of labour saving agronomic practices.
- Comparison of dryland and irrigated production in relation to yield and quality.
- Assessment of the feasibility of direct seeding and transplanting under dryland and irrigated conditions.
- Determination of stage and method of harvesting practices (primary processing) to increase recovery and to maintain quality.

Some of the observations from early research indicated considerable winter-kill in St. John's Wort cultivars under dryland compared to irrigated production. Effective agronomic practices are essential to consistently produce superior yields of high quality herbs.

Project Objectives

St. John's Wort is a perennial. Flowering tops are harvested for commercial use as the flowers and leaves are found to contain higher levels of hypericin. Success and sustainability of herb production depends on producing a high quality crop consistently and economically. The issues include mechanization to reduce labour cost, agronomics to maximize yield and improve quality as well as to minimize winter-kill. Plant growth characteristics and harvest height can affect yield and quality. Plant growth and flowering habit can be a function of many factors including genotype, population density, winter survival, and growing conditions. This project is designed to develop cost-effective agronomic practices for commercial scale production St. John's Wort in Saskatchewan. Emphasis is placed on reducing manual labour through mechanization while maximizing yield and improving quality.

This study examines the effects of mulching, plant spacing and harvest height on yield and quality attributes of St. John's Wort cultivars grown under irrigation and dryland. Studies were conducted 2002 through 2005.

Effect of Plant Spacing and Harvest Height on Winter-kill and Productivity of St. John's Wort Cultivars grown under Irrigation and Dryland:

Summary

- Soil salinity caused significant yield depression in herb yields in all cultivars. Yields decreased progressively with time under this poor soil condition.
- Cultivars Elixir and Topas suffered less winter-kill, grew more vigorously, and produced higher herb yields than Helos, New Stem and Standard St. John's wort.
- When planted in 60 cm rows, 15 cm between plant spacing within the row produced higher herb yields than 30 cm within-row spacing.

St. John's Wort is a perennial. Flowering tops are harvested for commercial use as the flowers and leaves are found to contain higher levels of hypericin. Plant growth characteristics and harvest height can affect yield and quality. Plant growth and flowering habit can be a function of many factors including genotype, population density, and growing conditions. This study examines the effects of plant spacing height on yield attributes of St. John's Wort cultivars grown under irrigation and dryland.

Treatments:

Biotype:	Standard, New Stem, Elixir, Topaz, Helos
Within-row spacing:	15, 30 cm (6, 12 in)
Growing condition:	Irrigation
Crop establishment:	2002
Harvest height:	Top half of the plants
Study period:	2003 and 2004

Results

2002:
The crop was established in 2002 and harvested during the summer of 2003 and 2004. The crop did not produce sufficient growth to harvest during the establishment year, i.e. 2002. Poor soil conditions (i.e. slight salinity) caused severe yield depressions during the subsequent harvest years.

2003:
St. John's wort cultivar Elixir suffered the lowest incidence of winter-kill compared to the other cultivars (Table 1). The crop that was planted at 30 cm within-row spacing suffered greater winter-kill than the crop planted at 15 cm plant spacing.

Elixir and Topas produced superior herb yields compared to the other cultivars (Table 1). The higher yield responses for Elixir and Topas appears to be a function of less winter-kill in these cultivars.

Closer plant spacing of 15 cm within-row produced significantly higher herb yields than wider plant spacing of 30 cm (Table 1).

2004:
The test plots showed uneven stand and weak plant growth. This resulted in highly variable yields evidenced by high coefficient of variation (130%). Poor growth and low herb yields during 2004 was due to inadequate drainage and salinity conditions (Table 2).
Topas and Elixir produced superior herb yields compared to the other cultivars (Table 2).

Plant spacing had no effect on herb yields, although closed spacing produced slightly (non-significant) yield than wider spacing.

Effect of Nitrogen Application and Straw Mulching on Winter-kill and Productivity for St. John's Wort Cultivars Grown Under Irrigation and Dryland:

Summary

- St. John's wort cultivars suffered severe winter-kill and the incidence was more pronounced under dryland production relative to irrigated production. After two years of field production, the dryland crop had negligible survival. Under irrigation, an average survival rate of 36% to 60% was observed depending on the cultivar. Elixir and Topas recorded the highest survival of 59%-60% from the original stand.
- Mulching reduced winter-kill and increased herb yield under dryland but had no effect under irrigated production.
- Nitrogen application caused significant winter-kill and yield reduction in all cultivars under both dryland and irrigated production. This effect was more pronounced under higher nitrogen application rate.

Proper fertility management is an important criteria for successful crop production. Different crops/cultivars respond differently to the type (e.g. nitrogen, phosphorus, potassium), amount, and timing (crop stage) of fertilizer and this can be influenced by soil, climate, and growing conditions under which the crop is produced. There is no information on fertility management for commercial production of St. John's wort in Saskatchewan or in Canada. This study examines the response of nitrogen application on the incidence of winter-kill and herb yield for St. John's wort Topas, Helos, Elixir, New Stem, and Standard.

Treatments:

Nitrogen rates: 0, 100 and, 200 kg N/ha
Mulching: No mulch and straw mulch
Separate trials were conducted for biotypes Topas, Helos, Elixir, New Stem, and Standard
Growing condition: Irrigation and dryland
Crop establishment: 2003
Study period: 2004 and 2005

Results

The crop was established in 2003 and harvested during the summer of 2004 and 2005.

2004:
The relatively cool weather during the 2004 growing season resulted in delayed flowering

and poor growth both under dryland and irrigation. This resulted in only one cut under both growing conditions. Yield responses to mulching and nitrogen application under dryland and irrigation are summarized in Table 3 and Table 4 respectively. On the average, dry herb yields were higher under irrigated production than dryland production. This was due to more winter-kill and less vigorous growth under dryland relative irrigated production.

Dryland:
Under dryland, the average dry herb yield ranged between 0.15 and 0.72 t/ha (Table 3). Elixir and Topas produced higher herb yields relative to Helos, New Stem, or Standard. Mulching produced significantly higher herb yields than the un-mulched crop.

Nitrogen application had a negative effect on herb yields. The crop that did not receive any fertilizer nitrogen produced the highest herb yield for all cultivars.

Applying higher rates of nitrogen resulted in progressive yield decline compared to the no nitrogen crop and the differences reached significant proportion for Elixir and New Stem.

Irrigation:
Under irrigation, dry herb yields ranged between on the average 0.1 and 1.9 t/ha among the various cultivars (Table 4). Elixir, Helos, and Topas produced higher herb yields than New Stem or Standard.

Straw mulch mulching was beneficial for Elixir, mulching resulted in 77% higher yield than the un-mulched crop. Mulching had no effect on herb yield for the other cultivars.

Nitrogen fertilization depressed herb yields for all cultivars. Severe yield reductions were observed for the 200 kg N/ha rate.

2005:
The dryland crop suffered severe winter-kill, consequently the dryland component of this trail had to be abandoned.

The irrigated crop showed less winter-kill than the dryland crop. Two years after establishment, Elixir and Helos retained the highest stand, i.e. 59% and 60% respectively from the original stand (Table 5). Helos, Standard, and New Stem recorded 48%, 37% and 36% survival respectively from the original stand. Nitrogen application increased the incidence of winter-kill in all cultivars of St. John's wort.

Straw mulching had no effect on dry herb yields for all St. John's Wort cultivars except for Helos where mulching produced higher yield than no mulch (Table 6). Nitrogen fertilization depressed herb yield for all biotypes (Table 6).

Effect of Straw Mulch, Harvest Height and Harvest Frequency on Dry Herb Yield for St. John's Wort cultivars Grown Under Irrigation and Dryland:

Treatments:

Cultivars:	Standard, Elixir, Topaz, New Stem, Helos
Cutting height:	Top-1/3, Top-2/3
Cutting frequency:	One cut, two cuts
Mulching:	No mulch, straw mulch
Growing condition:	Irrigation and dryland
Crop establishment:	2001, 2002, 2003

Summary

- The incidence of winter kill and dry herb yields of St. John's wort cultivars Topas, Helos, Elixir, New Stem, and Standard varied from year-to-year and growing condition, i.e. irrigation or dryland.
- Herb yields were generally higher and winter-kill incidence was less under irrigated production compared to dryland production. Under dryland, there could be complete winter-kill.
- Under dryland, only one cut was possible in a season. However, under irrigation two cuts were possible when the season was favourable (i.e. warm summer and fall) whereas, only one cut was possible when the growing season was cooler.
- Under irrigation, herb yields were generally similar when harvest was taken at a higher level (Top-1/3) or at a lower level (Top-2/3). By contrast, under dryland, lower cutting height produced higher herb yields than higher cutting height.
- Straw mulching reduced the incidence of winter-kill. Straw mulch was more beneficial for dryland than for the irrigated crop.

Results

2002:

The crop was established in 2001. St. John's Wort cultivars Standard, Topas, Anthos, and Elixir suffered considerable winter-kill during the winter of 2001/2002 causing severe yield losses. It was not possible to collect any meaningful data due to crop loss. Following is some basic information on the incidence of winter-kill and related yield data for St. John's wort cultivars.

Unmulched St. John's Wort suffered severe winter kill under both dryland and irrrigated production (Table 7). Without mulching, the highest survival was 8% for Topas under irrigation. Survival for the other cultivars were 2% or less under irrigation and dryland. Straw mulching improved survival both under both growing conditions. The percent survival ranged from 10% to 55% for the various cultivars under irrigation and between 53% and 63% under dryland (Table 7).

The plants that escaped winter-kill appeared weak and only one cut was possible under bothe dryland and irrigated production. This resulted in very low herb yields (Table 8). The highest yield obtained was 0.15 t/ha of dry herb for unmulched crop and 1.81 t/ha of dry herb for mulched crop.

2003:

The effects of cutting height (Top-1/3 or top-2/3), cutting frequency (one or two cuts per year), and mulching (straw mulch or no mulch) on the incidence of winter-kill, and herb

yields for the crop established in 2002 under dryland and irrigation are summarized in Table 9 and Table 10 respectively.

The winter-kill incidence was lower under irrigation than under dryland. Under dryland the winter-kill ranged between 42% and 64% (Table 9), whereas, under irrigation the winter-kill incidence ranged between 33% and 40% (Table 10). Mulching significantly reduced winter-kill under dryland production, while mulching had no effect on winter-kill under irrigated production. Cutting height and cutting frequency did not affect winter-kill under both dryland and irrigated production.

For both dryland and irrigated production, the crop where two cuts were taken produced higher total herb yields than the crop that was harvested only once.

Lower cutting height (i.e. top-2/3) produced higher total herb yields relative to higher cutting height (i.e. top-1/3) under dryland production (Table 9). This was due higher yield with lower cutting height than the higher cutting height during the first harvest. Yields were similar for both cutting heights during the second cut. By contrast, under irrigated production, cutting height had no effect on herb yields during the first cut, second cut that resulted in similar herb yields for both cutting heights (Table 10).

Straw mulching resulted in higher total herb yields relative to no mulching under both dryland (Table 9) and under irrigation (Table 10). This yield increase was due to greater production during the first cut with straw mulch than without mulch. The second cut produced similar herb yields for mulch and no-mulch treatments.

2004:
The effects of cutting height (Top-1/3 or top-2/3), cutting frequency (one or two cuts per year), and mulching (straw mulch or no mulch) on the incidence of winter-kill, and herb yields for the crop established in 2002 under dryland and irrigation are summarized in Table 11 and Table 12 respectively.

Due to poor growth as a result of cool wet weather, only one cut was possible during this season. It is interesting to note that the crop that was harvested only once in the previous year (i.e. on the 1 cut treatment) generally produced higher herb yields than the crop that was harvested twice. The differences were more pronounced under dryland (Table 11) than under irrigation (Table 12).

The effects of cutting height (Top 1/3 or top 2/3), cutting frequency (one or two cuts per year), and mulching (straw mulch or no mulch) on the incidence of winter-kill, and herb yields under dryland and irrigated production are summarized in Tables 11 and 12 respectively.

Under dryland, straw mulching resulted in higher herb yields relative to no mulching for all cultivars (Table 11). The differences reached significant proportion for Topas, Helos, and Standard. Under irrigation, mulching had no effect on herb yields for all cultivars (Table 12)

Lower cutting height (top 2/3) generally produced higher herb yields relative higher cutting height (top 1/3) both under dryland (Table 11) and under irrigation (Table 12).

2005:
The effects of cuttiing height (Top-1/3 or top-2/3), cutting frequency (one or two cuts per year), and mulching (straw mulch or no mulch) on the incidence of winter-kill, and herb

yields for the crop established in 2002 and 2003 under dryland and irrigation were evaluated this season. The crop survival percent and yield responses for dryland the crop established in 2002 are are summarized in Table 13 and Table 14 respectively. The corresponding data for the irrigation crop are presented in Table 15, and Table 16 respectively. Due to poor growth, only one cut was possible during this season. Cutting frequency was not taken into consideration for the statistical analysis as only one cut was possible in 2005.

2002 Establishment:
The dryland crops of Helos and Topas were completely winter-killed while about 66% to 70% of Elixir, 65% to 78% of New Stem, and 57% to 66% of Standard survived the winter (Table 13). Crop survival was not affected by cutting height or mulching.

Under dryland, dry herb yields ranged from 3.4 to 3.8 t/ha for Elixir, 3.4 to 4.3 t/ha fo new Stem, and 2.8 to 4.5 t/ha for Standard (Table 14). Lower cutting (i.e. Top-2/3 harvest) produced higher yields than the higher harvest height (i.e. Top-1/3) and the yield difference reached significant proportion for Elixir and Standard and not to New Stem.

Under irrigation, all cultivars survived and the degree of survival varied among cultivars. The survival percentage was 19% to 25% for Topas, 32% to 39% for Helos, 43% to 47% for Elixir, 56% to 67% for New Stem, and 35% to 43% for Standard (Table 15). Cutting height or mulching had no effect of crop survival for all the cultivars.

Under irrigation, dry herb yields ranged from 0.6 to 1.0 t/ha for Topas, 2.2 to 2.6 t/ha for Helos, 2.8 to 3.3 t/ha for Elixir, 3.6 to 5.0 t/ha for new Stem, and 4.0 to 4.7 t/ha for Standard (Table 16). Cutting height or mulching had no effect of crop survival for all the cultivars.

2003 Establishment:
The dryland crop established in 2003 was abandoned as more than 90% the crop (all cultivars) were winter killed. The effects of cutting height cutting frequency and mulching on the incidence of winter-kill, and herb yields for the irrigated crop established in 2003 are summarized in Table 17 and Table 18 respectively. Cutting frequency was not taken into consideration for the statistical analysis as only one cut was possible in 2005.

Under irrigation, all cultivars survived and the degree of survival varied among cultivars. The survival percentage was 71% to 76% for Topas, 69% to 75% for Helos, 69% to 81% for Elixir, 84% for New Stem, and 58% to 68% for Standard (Table 17). Cutting height had no effect of crop survival for all the cultivars. Straw mulch increased survival for Elixir but had no effect on other cultivars.

Under irrigation, dry herb yields ranged from 2.1 to 3.8 t/ha for Topas, 2.2 to 4.0 t/ha for Helos, 1.7 to 3.2 t/ha for Elixir, 2.0 to 2.9 t/ha for new Stem, and 2.0 to 3.4 t/ha for Standard (Table 18). Lower cutting height produced significantly higher yields for all cultivars. Straw mulch produced higher herb yields relative to no mulch for Elixir but had no effect on other cultivars.

Table 1: Plant spacing effects on winter-kill incidence and herbage yield for St. John's wort grown under irrigation: 2003			
Treatment	Winter-kill (%)	Fresh herb yield (t/ha)	Dry herb yield (t/ha)
Cultivar:			
Elixir	30.1	6.06	2.16
Helos	54.4	2.22	0.75
New Stem	53.7	2.69	0.91
Standard	49.2	2.66	0.87
Topas	47.1	3.78	1.25
Plant spacing:			
15 cm	40	4.59	1.54
30 cm	54.2	2.38	0.83
Analyses of variance			
Source:			
Cultivar	**(14.0)	***(1.47)	***(0.55)
Spacing	***(8.9)	***(0.93	***(0.35)
Cultivar x Spacing	ns	ns	ns
C.V.(%)	29.1	41.2	45.0

, *, and ns indicate significance at P<0.01, 0.001 levels of probability and not significant respectively.
Values within parentheses indicate significance at 5.0% level of probability.

Table 2: Plant spacing effects on herbage yield for five St. John's Wort biotypes grown under irrigation: 2004	
Treatment	Dry herb yield (t/ha)
Cultivar:	
Elixir	1.02
Helos	-
New Stem	0.28
Standard	0.35
Topas	1.06
Plant spacing:	
15 cm	0.67
30 cm	0.41
Analysis of variance	
Source:	
Cultivar	***(0.72)
Spacing	ns
Cultivar x Spacing	ns
C.V.(%)	130

***, and ns indicate significance at P<0.001 level of probability and not significant respectively. Values within parentheses indicate significance at the 5.0% level of probability.

Table 3. Effects of mulching and nitrogen application rate on dry herb yield for St. John's Wort cultivars under dryland production: 2004

Treatment	Dry herb yield (t/ha)				
	Topas	Helos	Elixir	New Stem	Standard
Mulching:					
No mulch	0.81	0.02	0.40	0.20	0.03
Straw mulch	0.62	0.27	0.97	0.96	0.32
Nitrogen rate (kg N/ha):					
0	0.47	0.24	1.07	0.7	0.21
100	0.30	0.10	0.78	0.73	0.23
200	0.28	0.09	0.21	0.31	0.08
Analyses of variance					
Source:					
Mulching	*	***	*	***	*
Nitrogen rate	ns	ns	*	**	ns
Mulching x Nitrogen rate	ns	ns	ns	ns	ns
C.V. (%)	47	171	74	53	149

*, **, ***, and ns indicate significance at P<0.05, 0.01, 0.001 levels of probability and not significant respectively.

Table 4. Effects of mulching and nitrogen application rate on dry herb yield for St. John's Wort cultivars under irrigated production: 2004

Treatment	Dry herb yield (t/ha)				
	Topas	Helos	Elixir	New Stem	Standard
Mulching:					
No mulch	1.19	0.93	1.39	0.33	0.48
Straw mulch	1.11	1.20	2.47	0.63	0.47
Nitrogen rate (kg N/ha):					
0	1.95	1.79	2.65	0.94	1.05
100	0.96	1.03	1.92	0.32	0.26
200	0.53	0.37	1.21	0.18	0.12
Analyses of variance					
Source:					
Mulching	ns	ns	**	ns	ns
Nitrogen rate	**	***	*	**	**
Mulching x Nitrogen rate	ns	ns	ns	ns	ns
C.V. (%)	67	47	45	80	95

*, **, ***, and ns indicate significance at P<0.05, 0.01, 0.001 levels of probability and not significant respectively.

Table 5. Effects of mulching and nitrogen application on crop survival for St. John's Wort biotypes under irrigated production: 2005

Treatment	Percentage of original plant stand (%)				
	Standard	New Stem	Elixir	Topas	Helos
Mulching:					
No mulch	37.5	33.3	55.2	57.3	44.4
Straw mulch	36.8	38.5	63.2	61.8	52.4
Nitrogen rate (kg N/ha):					
0	60.4	51	76.6	78.1	69.8
100	30.7	35.9	56.3	60.4	47.4
200	20.3	20.8	44.8	40.1	28.1
Analyses of variance					
Source:					
Mulch	ns	ns	ns	ns	ns
Nitrogen	***(14.0)	**(17.0)	**(17.9)	**(18.5)	***(14.8)
Mulch x Nitrogen	ns	ns	ns	ns	ns
C.V. (%)	35.5	44.5	28.4	29.2	28.7

, *, and ns indicate significance at P<0.01, <0.001 levels of probability and not significant respectively. Values within parentheses indicate significance at 5.0% level of probability.

Table 6. Effects of mulching and nitrogen application on herbage yield for St. John's Wort biotypes under irrigated production: 2003 planting and 2005 harvest					
Treatment	Dry herb yield (t/ha)				
	Standard	New Stem	Elixir	Topas	Helos
Mulching:					
No mulch	2.16	3.35	3.02	3.19	3.36
Straw mulch	2.48	3.36	3.8	3.05	4.86
Nitrogen rate (kg N/ha):					
0	3.83	4.58	4.3	3.93	5.10
100	1.86	3.68	3.38	3.31	4.47
200	1.26	1.81	2.54	2.13	2.76
Analyses of variance					
Source:					
Mulch	ns	ns	ns	ns	**(1.14)
Nitrogen	***(0.98)	***(1.17)	*(1.40)	*(1.46)	**(1.40)
Mulch x Nitrogen	ns	ns	ns	ns	ns
C.V. (%)	39.7	32.64	38.7	44.0	31.9

*, **, ***, and ns indicate significance at P<0.05, <0.01, <0.001 levels of probability and not significant respectively. Values within parentheses indicate significance at 5.0% level of probability.

Table 7. Effect of straw mulch on crop survival for St. John's wort grown under irrigation and dryland: 2002

Cultivar	Crop survival (Percentage of the original plant stand)			
	Irrigation		Dryland	
	No mulch	Straw mulch	No mulch	Straw mulch
Standard	2	10	2	46
Topas	8	55	0	55
Elixir	3	36	0	53
Anthos	1	16	0	63
Average	4	29	1	54

Table 8. Effect of straw mulch on dry herb yield for St. John's wort grown under irrigation and dryland: 2002

Cultivar	Irrigation- Dry herb yield (t/ha)		Dryland- Dry herb yield (t/ha)	
	No mulch	Straw mulch	No mulch	Straw mulch
Standard	0.01	0.3	0.06	1.08
Topas	0.15	1.52	0	1.81
Elixir	0.05	1.33	0	1.11
Anthos	0.03	0.69	0	1.81

Table 9: Effects of cutting height, cutting frequency and mulching of winter-kill incidence and herbage yield for Topas St. John's Wort grown under dryland: 2003

Treatment	Winter-kill (%)	Dry herb yield (t/ha)		
		Cut-1	Cut-2	Total
Cutting height:				
Top-1/3	52	0.24	0.66	0.90
Top-2/3	54	0.6	0.54	1.14
Cutting frequency:				
1-cut/year	48	0.38	-	0.38
2-cuts/year	58	0.46	1.20	1.66
Mulching:				
No mulch	64	0.2	0.46	0.66
Straw mulch	42	0.64	0.74	1.38
Analyses of variance				
Source:				
Cutting height (H)	ns	**	ns	ns
Cutting frequency (F)	ns	ns	***	***
Mulching (M)	***	***	ns	**
H x F	ns	ns	ns	ns
H x M	ns	**	ns	ns
F x M	ns	ns	ns	ns
H x F x M	ns	ns	ns	ns
C.V. (%)	31.5	71.8	88.3	71.3

, *, and ns indicate significance at P<0.01, 0.001 levels of probability and not significant respectively.

Table 10: Effects of cutting height, cutting frequency and mulching of winter-kill incidence and herbage yield for Topas St. John's Wort grown under irrigation: 2003				
Treatment	Winter-kill (%)	Dry herb yield (t/ha)		
		Cut-1	Cut-2	Total
Cutting height:				
Top-1/3	37	1.02	0.84	1.86
Top-2/3	36	1.28	1.11	2.39
Cutting frequency:				
1-cut/year	37	1.17	-	1.17
2-cuts/year	36	1.13	1.95	3.08
Mulching:				
No mulch	40	0.69	0.96	1.65
Straw mulch	33	1.61	1.0	2.61
Analyses of variance				
Source:				
Cutting height (H)	ns	ns	ns	ns
Cutting frequency (F)	ns	ns	***	***
Mulching (M)	ns	***	ns	*
H x F	ns	ns	ns	ns
H x M	ns	ns	ns	ns
F x M	ns	ns	ns	ns
H x F x M	ns	ns	ns	ns
C.V. (%)	33.0	67.6	82.1	58.6

*, **, ***, and ns indicate significance at P<0.05, 0.01, 0.001 levels of probability and not significant respectively.

Table 11. Effects of cutting height, cutting frequency, and straw mulching on dry herb yield for St. John's wort cultivars grown under dryland production: 2004

Treatment	Dry herb yield (t/ha)				
	Topas	Helos	Elixir	New Stem	Standard
Cutting height:					
Top-1/3	0.28	0.38	0.92	1.25	1.78
Top-2/3	0.32	0.74	1.38	2.05	2.32
Cutting frequency:					
1-cut/year	0.43	0.93	1.54	2.41	2.92
2-cuts/year[1]	0.18	0.19	0.76	0.9	1.18
Mulching:					
No mulch	0.11	0.2	1.13	1.45	1.46
Straw mulch	0.5	0.92	1.17	1.86	2.64
Analyses of variance					
Source:					
Cutting height (H)	ns	*	*	**	ns
Cutting frequency (F)	ns	***	***	***	***
Mulching (M)	*	***	ns	ns	**
H x F	ns	ns	*	ns	ns
H x M	ns	*	ns	ns	ns
F x M	ns	*	*	ns	ns
H x F x M	ns	ns	ns	ns	*
C.V. (%)	142	87	46	35	51

[1] Only one cut was taken in this treatment.
*, **, ***, and ns indicate significance at P<0.05, 0.01, 0.001 levels of probability and not significant respectively.

Table 12. Effects of cutting height, cutting frequency and mulching on dry herb yield for St. John's Wort cultivars grown under irrigated production: 2004					
Treatment	Dry herb yield (t/ha)				
	Topas	Helos	Elixir	New Stem	Standard
Cutting height:					
Top-1/3	0.22	0.84	1.6	1.70	2.03
Top-2/3	0.47	0.7	1.69	1.91	1.98
Cutting frequency:					
1-cut/year	0.45	0.92	1.95	1.9	2.35
2-cuts/year	0.24	0.62	1.33	1.71	1.66
Mulching:					
No mulch	0.21	0.71	1.95	2.02	2.52
Straw mulch	0.48	0.83	1.34	1.59	1.48
Analyses of variance					
Source:					
Cutting height (H)	ns	ns	ns	ns	ns
Cutting frequency (F)	ns	ns	ns	ns	ns
Mulching (M)	ns	ns	ns	ns	**
H x F	ns	ns	ns	ns	ns
H x M	ns	ns	ns	*	ns
F x M	ns	ns	ns	ns	ns
H x F x M	ns	ns	ns	ns	ns
C.V. (%)	113	83	68	54	53

*, ** and ns indicate significance at P<0.05, 0.01 levels of probability and not significant respectively.

Table 13. Effects of cutting height, cutting frequency and mulching on crop survival for St. John's Wort cultivars grown under dryland: 2002 planting and 2005 harvest					
Treatment	Crop survival (Percentage of the original plant stand)				
	Topas	Helos	Elixir	New Stem	Standard
Cutting height:					
Top-1/3			71.1	71.4	62
Top-2/3	Total	Total	69.5	70.8	61.5
Mulching:	winter	winter			
No mulch	kill	kill	66.2	64.1	57.3
Straw mulch			74.5	78.1	66.2
Analyses of variance					
Source:					
Cutting height			ns	ns	ns
Mulching			ns	ns	ns
Cutting height x Mulching	-	-	ns	ns	ns
C.V. (%)			20.3	32.2	31.2
ns indicate non-significant treatment effects.					

Table 14. Effects of cutting height, cutting frequency and mulching on herbage yield for St. John's Wort cultivars grown under dryland: 2002 planting and 2005 harvest					
Treatment	Dry herb yield (t/ha)				
	Topas	Helos	Elixir	New Stem	Standard
Cutting height:					
Top-1/3			3.11	3.37	2.8
Top-2/3	Total	Total	3.8	4.33	4.48
Mulching:	winter	winter			
No mulch	kill	kill	3.39	3.6	3.31
Straw mulch			3.51	4.09	3.98
Analyses of variance					
Source:					
Cutting height			*	ns	**
Mulching			ns	ns	ns
Cutting height x Mulching			ns	ns	ns
C.V. (%)			27.6	38.4	36.7
*, ** and ns indicate significance at P<0.05, 0.01 levels of probability and not significant respectively.					

Table 15. Effects of cutting height, cutting frequency and mulching on crop survival for St. John's Wort cultivars grown under irrigation: 2002 planting and 2005 harvest					
Treatment	Crop survival (Percentage of the original plant stand)				
	Topas	Helos	Elixir	New Stem	Standard
Cutting height:					
Top-1/3	24	38.5	46.6	66.7	35.4
Top-2/3	19.3	31.5	44	55.7	43
Mulching:					
No mulch	18.5	36.2	47.9	63..0	38.5
Straw mulch	24.7	33.9	42.7	59.4	39.8
Analyses of variance					
Source:					
Cutting height	ns	ns	ns	ns	ns
Mulching	ns	ns	ns	ns	ns
Cutting height x Mulching	ns	ns	ns	ns	ns
C.V. (%)	69.0	47.3	30.0	23.8	27.4
ns indicate non-significant treatment effects.					

Table 16. Effects of cutting height, cutting frequency and mulching on herbage yield for St. John's Wort cultivars grown under irrigation: 2002 planting and 2005 harvest					
Treatment	Dry herb yield (t/ha)				
	Topas	Helos	Elixir	New Stem	Standard
Cutting height:					
Top-1/3	0.61	2.34	2.79	4.41	4
Top-2/3	0.95	2.43	3.29	4.16	4.67
Mulching:					
No mulch	0.79	2.58	3.22	3.62	4.29
Straw mulch	0.77	2.19	2.86	4.95	4.38
Analyses of variance					
Source:					
Cutting height	ns	ns	ns	ns	ns
Mulching	ns	ns	ns	ns	ns
Cutting height x Mulching	ns	ns	ns	ns	ns
C.V. (%)	65.13	54.6	25.0	61.5	28.6
ns indicate non-significant treatment effects.					

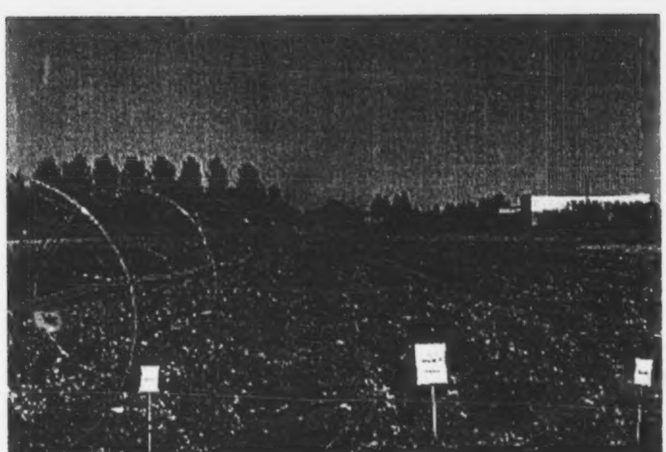
Table 17. Effects of cutting height, cutting frequency and mulching on crop survival for St. John's Wort cultivars grown under irrigation: 2003 planting and 2005 harvest					
Treatment	Percentage of original stand (%)				
	Topas	Helos	Elixir	New Stem	Standard
Cutting height:					
Top-1/3	72.4	71.6	72.6	84.4	66.9
Top-2/3	74.5	72.1	76.8	83.8	58.6
Mulching:					
No mulch	75.5	69	68.5	84.1	58.1
Straw mulch	71.4	74.7	81	84.1	67.5
Analyses of variance					
Source:					
Cutting height	ns	ns	ns	ns	ns
Mulching	ns	ns	*	ns	ns
Cutting height x Mulching	ns	ns	ns	ns	ns
C.V. (%)	17.6	26.2	22.4	13.3	32.3

* and ns indicate significance at P<0.05 level of probability and not significant respectively.

Table 18. Effects of cutting height, cutting frequency and mulching on herbage yield for St. John's Wort cultivars grown under irrigation: 2003 planting and 2005 harvest					
Treatment	Dry herb yield (t/ha)				
	Topas	Helos	Elixir	New Stem	Standard
Cutting height:					
Top-1/3	2.11	2.15	1.71	2.02	1.98
Top-2/3	3.81	3.99	3.22	2.9	3.37
Mulching:					
No mulch	2.93	2.97	1.98	2.13	2.57
Straw mulch	2.99	3.18	2.95	2.79	2.67
Analyses of variance					
Source:					
Cutting height	***	***	***	*	**
Mulching	ns	ns	***	ns	ns
Cutting height x Mulching	ns	ns	ns	ns	ns
C.V. (%)	30.4	33.2	30.6	40.1	40.6

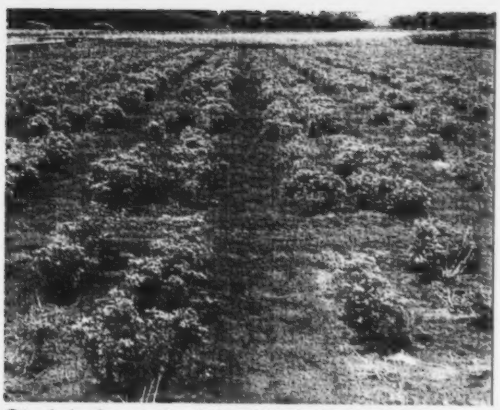
*, **, *** and ns indicate significance at P<0.05, 0.01, 0.001 levels of probability and not significant respectively.

Transplanting St. John's Wort.

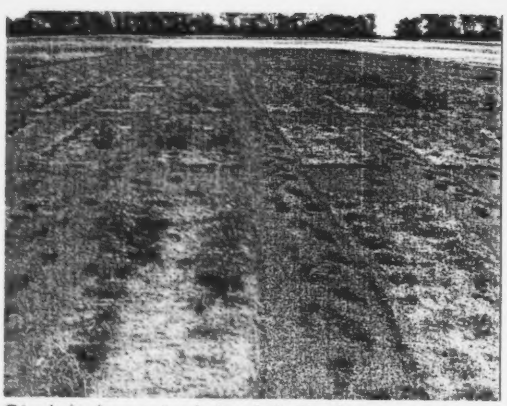


Irrigating St. John's wort with a Wheel-move system

St. John's wort cultivars.



St. John's wort winter-kill: Irrigated crop.



St. John's wort winter-kill: Dryland crop.


Harvesting St. John's wort.

*Supplement to the Final Report of

AFIF Project 20010382

Growing Higher Value Crops with Irrigation

***This supplement reports on research into the crops Echinacea, Feverfew, Chamomile and Stinging Nettle. Work on these crops was conducted between the years 1999 and 2003. This work was previously reported in the annual progress reports on this project.**

Summary

Echinacea angustifolia:

- Can be established through direct seeding or transplanting for commercial production.
- Irrigation and dryland produces similar yields.
- Optimum root yields can be obtained two or three years after planting.
- Delaying harvest to the fourth year results in substantial yield reduction. This yield loss was more severe under dryland than under irrigation.
- Yield losses are mainly due to winter-kill.
- Winter-kill incidence is higher under dryland relative to irrigated production.
- Seeding rate effects were not clear with direct seeding. Optimum seeding rate appears to be 120 to 150 seeds/m^2
- Nitrogen and phosphorus application did not appear to have any effect on direct seeded or transplanted crops.
- Row spacing had no effect on root yields of direct seeded or transplanted crops,
- Closer 15 cm in-row spacing produced higher root yields than wider 30 cm in-row spacing.

Feverfew:

- Highly variable herbs yields among years.
- No clear indication on plant spacing effects under dryland or irrigated production.
- Harvesting at pre-flower stage produced lower herb yields than harvesting at 10% flower or 100% flower.
- Yields at 10% flower and 100% flower were somewhat similar.
- Nitrogen and phosphorus fertilizer application had no effect on herb yield.

German Chamomile:

- Nitrogen, phosphorus, and potassium application produced variable results. Generally there was no added benefits to fertilizer application. However in one year, nitrogen increased herb yields under dryland production but had no effect under irrigated production.
- Closer (15 cm) within-row spacing produced higher herb yields than wider (30 cm) within-row spacing under both dryland and irrigated production.
- Machine and hand harvesting produced inconsistent responses. In one year, hand harvesting was superior to machine harvesting and in the other opposite trend was observed.

Stinging Nettle:

- Perennial, harvests taken annually on the same crop similar to alfalfa.
- Transplants raised during the previous fall and over-wintered outyielded current spring transplants only during the first year of production and not in the following years.
- Herb yields increased substantially during the second year.
- High yields were maintained under irrigated production.
- Under dryland production, yields dropped sharply in the fourth year.
- Fertilizer (N, P, K) application had no effect on yield.
- Lower cutting height produced higher herb yield than higher cutting height only in the first year, but had no difference in the subsequent years.

Echinacea angustifolia

Direct Seeded Echinacea angustifolia

Background:
Echinacea angustifolia can be established either by direct seeding or transplanting. Inherent seed dormancy and the requirement of light for germination renders *Echinacea* a difficult crop for direct seeding. Consequently, *Echinacea* is generally produced using transplants. Raising *Echinacea* from transplants requires high capital and labour inputs. These studies examine the feasibility of commercial production *Echinacea angustifolia* by direct seeding and related agronomic practices for dryland and irrigated production.

Seeding Rate and Row Spacing Effects Under Dryland and Irrigated Production

Treatments:

Seeding rate:	60, 90, 120, 150, 180 seeds/m^2
Row spacing:	41, 61 cm
Growing conditions:	Dryland and irrigation
Seeding date:	July 2, 1997.
Harvest date:	Fall 1999, 2000, 2001

Results

Year-1 harvest:
Dry root yield s are generally comparable across harvest stages under both dryland and irrigated production (Table 1). Root yields were highest when harvested two or three years after establishment. Root yields declined during the fourth year and this decline was marked under dryland relative to irrigated production (Figure 1). The yield decline during the fourth year was due to winter-kill and aster yellows. generally similar. Considerable winter-kill in the dryland crop caused significant reduction in root yields in the fourth year.

Yield response to seeding rate was variable across harvest dates and growing conditions. No identifiable trends were observed in relation to seed rate and dry root yield. The relatively high coefficients of variation is likely due to variability winter-kill and aster yellows. Dry root yields during the second, third, and fourth year harvests in response to seeding rate and row spacing effects under

Year-2 harvest:
Under dryland, the lowest seeding rate of 60 seeds/m^2 produced the lowest dry root yield (876 kg/ha) and increasing seeding rate produced higher root yields (Table 1). The highest yield (2089 kg/ha) was recorded for the 180 seeds/m^2 seeding rate.

Under irrigation, seeding rate had no effect on dry root yield and ranged from 1013 kg/ha for 90 seeds/m^2 to 1459 kg/ha for 120 seeds/m^2. Higher seeding rates produced lower yileds.

Row spacing (41, 61 cm) had no effect on dry root yield under both dryland and irrigated production (Table 1).

Year-3 harvest:
Seeding rate had no significant effect on root weight under dryland or irrigation. Generally, superior yields were obtained at higher seeding rates with optimal yields at 150 seeds/m^2 for irrigation and 180 seeds/m^2 for dryland.

Contrasting responses were observed for row-spacing effects under the two growing conditions. Under dryland the wider row spacing higher yield than the narrow row spacing. By contrast, under irrigation, the narrow row-spacing out-yielded the wider row-spacing.

Significant seeding-rate x row-spacing interaction was observed for the dryland crop but there were no identifiable trends for this interaction.

Year-4 harvest:
Echinacea angustifolia grown under irrigation produced on average over double the root yield than the dryland crop (Table 1).

Seeding rate or row spacing had no significant effect on root yields under dryland or irrigation. Dry root yields ranged between 327 kg/ha and 624 kg/ha under dryland and between 814 kg/ha and 1024 kg/ha under irrigation. Narrow and wide plant spacings produced similar root yields both under dryland and irrigation.

Table 1. Seeding rate and row spacing effects on dry-root yield for direct seeded *Echinacea angustifolia* grown under dryland and irrigation and harvested two, three, and four years after establishment

Treatment	Dry root yield (kg/ha)					
	Dryland			Irrigation		
	1999: Year-2	2000: Year-3	2001: Year-4	1999: Year-2	2000: Year-3	2001: Year-4
Seeding rate (seeds/m^2)						
60	876	750	327	1147	1157	940
90	1090	1237	326	1013	1158	814
120	1448	1318	624	1459	994	1010
150	1352	1119	401	1103	1801	966
180	2089	1480	511	1263	1343	1024
Row Spacing (cm)						
41	1272	1007	396	1218	1507	939
61	1457	1354	426	1177	1074	963
Analyses of Variance						
Source						
Seeding rate (S)	**(580)	ns	ns	ns	ns	ns
Row spacing (R)	ns	ns	ns	ns	*	ns
S x R	ns	*(981)	ns	ns	ns	ns
C.V. (%)	41.3	48.4	73.8	29.1	36.6	36.2

**, *, and ns indicate significance at P < 0.01, 0.05 levels of probability and not significant respectively. Values within parentheses are LSD estimates at 5.0% level of significance.

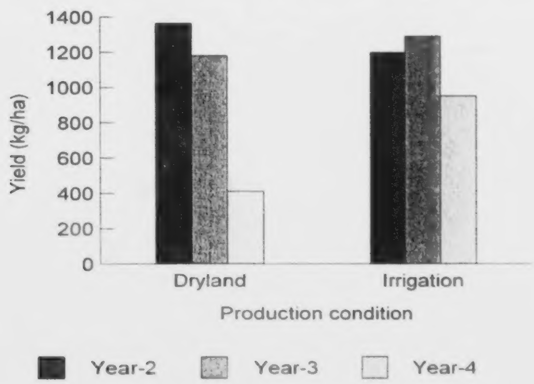


Figure 1. Dry root yields for Echinacea angustifolia w hen harvested two, three, and four years after planting under dryland and irrigated production.

Fertilizer Response Under Irrigated Production.

Background:

Presently, *Echinacea angustifolia* is grown under small scale organic and non-organic conditions. Effective fertilizer management is essential to increase yields and improve quality. Information on fertility management for direct-seeded *Echinacea angustifolia* is lacking and not available for Saskatchewan and the prairies. This study examines the effects of nitrogen and phosphorus application on root yield under irrigated production.

Treatments:

Nitrogen rate:	50, 100 kg N/ha.
Nitrogen application time:	Spring only, spring & fall (½ & ½).
Phosphorus rate:	50, 100 kg P_2O_5/ha.
Seeding rate:	120 seeds/m^2.
Row spacing:	61 cm.
Seeding date:	July, 1997.
Harvest date:	Fall 1999, 2000, and 2001
Production condition:	Irrigation.

Results

Response to nitrogen and phosphorus were observed only for the two-year crop. Nitrogen and phosphorus treatments had no effect during the third and fourth year harvests (Table 2).

In the two-year crop, application of 50 kg N/ha produced 1137 kg/ha of dry root. Adding 100 kg/ha nitrogen produced 17% higher root yield than 50 kg N/ha. Applying nitrogen once only in the spring or as two equal split applications in the spring and fall had no difference on root yield. Applying 100 kg P_2O_5/ha produced 1473 kg/ha dry root that was 48% higher than 50 kg P_2O_5/ha of applied phosphorus. During the third and fourth-year harvests, higher phosphorus rate slightly depressed yield although the differences were not significant.

Table 2. Nitrogen rate and timing and phosphorus rate effects on dry root yield of direct-seeded *Echinacea angustifolia* grown under irrigation and harvested two, three, and four years after establishment

Treatment	1999: Year-2	2000: Year-3	2001: Year-4
Nitrogen rate			
50 kg N/ha	1137	1296	1455
100 kg N/ha	1331	1218	1153
Nitrogen timing			
Spring	1228	1059	1210
Spring & fall	1239	1455	1398
Phosphorus rate			
50 kg P_2O_5/ha	995	1524	1430
100 kg P_2O_5/ha	1473	991	1179
Analyses of Variance			
Source			
Nitrogen rate (N)	*	ns	ns
Nitrogen Applic. (A)	ns	ns	ns
Phosphorus rate (P)	***	ns	ns
N x A	ns	ns	ns
N x P	ns	ns	ns
A x P	ns	ns	ns
N x A x P	ns	ns	ns
C.V. (%)	23.9	66.2	51.0

***, *, and ns indicate significance at P<0.001, 0.05 levels of probability and not significant respectively.
Values within parentheses are LSD estimates at 5.0% level of significance.

Direct Seeded Echinacea Angustifolia

Transplanted *Echinacea angustifolia*

Comparison of Types of Planting Material Under Irrigated Production

Background:

Raising *Echinacea* transplants in the spring requires heated greenhouse facilities at substantial additional cost. A'ernatively, transplants can be raised during the fall overwintered in a straw covered pit, and planted in the following spring. The second method does not require any specialized growth structures, thereby reducing costs. This study was designed to compare different methods of producing and over-wintering *Echinacea angustifolia* transplants on root yield.

Treatments:

Transplant production

Production season	Over-wintering	Container type
1. 1997 fall	Heated greenhouse	50-cell plug tray
2. 1997 fall	Straw covered pit	50-cell plug tray
3. 1998 spring	-	50-cell plug tray
4. 1998 spring	-	Bare root

Plant spacing: 15, 30 cm.

Stratification: Mixed with moist sand and placed in fridge (4°C) for four weeks.

Seeding: Seeds were sown on the surface of the germination medium and seedlings were transplanted pricked at the one true-leaf stage.

Treatment 1: The transplants were grown through the winter in a heated greenhouse.

Treatment 2: the transplants were over-wintered in a pit and the trays were covered with approximately 25-30 cm layer of straw.

Row spacing: 61 cm.

Growing conditions: Irrigation.

Planting date: June 11, 1998.

Harvest date: Fall 1999, 2000, and 2001.

Results

The average dry root yield during the year-2 harvest was 1005 kg/ha and delaying harvest till the third year resulted in almost doubling of the yield (1940 kg/ha). However, root yields dropped considerably to 677 kg/ha when harvested during the fourth year after planting (Table 3)

Two years after planting, transplants raised in the fall of 1997 and over-wintered in the pit, or greenhouse produced higher root yields than the bare root transplants raised in the spring of 1998 (Table 3). This superiority continued to the third and fourth years although the differences were not significant during Year-3 harvest.

Closer plant spacing , 60 cm x 15 cm consistently produced higher root yields than the wider spacing of 60 x 30 cm across the different harvest years. This yield superiority was 34% in year-2, 180% in year-3 and 32% in year-4.

Table 3. Effect of planting material and plant spacing on dry root yield for transplanted *Echinacea angustifolia* grown under dryland and harvested two, three, and four years after planting			
Treatment	Dry root yield (kg/ha)		
	1999: Year-2	2000: Year-3	2001: Year-4
Transplant type:			
Transplants raised during the fall of 1997 and grown in the greenhouse during winter	944	1860	622
Transplants raised during the fall of 1997 and over-wintered in a straw covered pit	1330	2312	686
Transplants raised in plug trays during the spring of 1998	1075	1968	956
Bare root transplants raised in the spring of 1998	670	1619	443
Plant spacing			
15 cm	1151	2859	769
30 cm	858	1020	584
Analyses of Variance			
Source			
Planting material	***(236)	ns	***(308)
Spacing	***	***	***
Planting material x spacing	ns	ns	ns
C.V. (%)	41.2	58.0	45.8
*** and ns indicate significance at P < 0.001 level of probability and not significant respectively. Values within parentheses are LSD estimates at 5.0% level of significance.			

Interactive Effects of Nitrogen, Phosphorus and Harvest Age Under Irrigated Production

Background:
Echinacea angustifolia roots are generally harvested three to four years after planting. Recent studies show that younger roots have a higher concentration of marker compounds than older roots. However, the root yield will be lower when harvested at an early stage. This study examines the influence of fertilizers on root yield for *Echinacea angustifolia* when harvested at different crop ages.

Treatments:

Nitrogen rate:	50, 100 kg N/ha.
Nitrogen timing:	Spring, Spring & fall (½ & ½).
Phosphorus rate:	50, 100 kg P_2O_5/ha.
Plant spacing:	60 x 30 cm.
Growing conditions:	Irrigation.
Planting date:	July 1997
Harvest date:	Fall, 1998, 1999, 2000, 2001

Results

Root yield of *Echinacea angustifolia* when harvested one year after planting was the lowest and yields increased progressively up to the third year (Figure 2). Delaying harvest to the fourth year resulted in a yield decline.

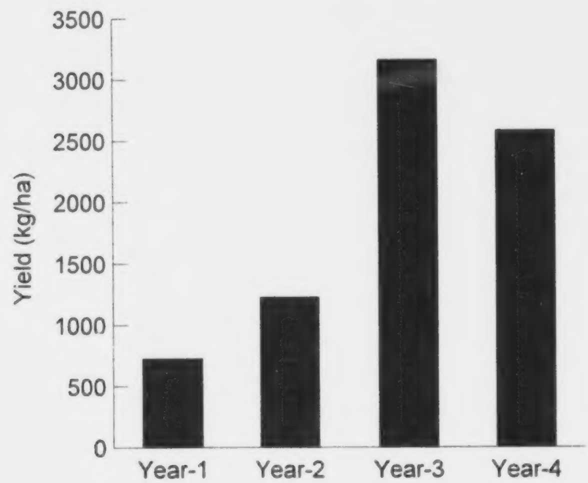


Figure 2. Dry root yields of *Echinacea angustifolia* when harvest at one, two, three, and four years after planting in the fertilizer study.

No statistically significant differences were observed for nitrogen rate, nitrogen timing, or phosphorus rate effects on dry root yield under irrigated production of transplanted *Echinacea angustifolia* (Table 4). However, it appeared that split applying nitrogen in the spring and in the fall produced higher yields than applying nitrogen only in the spring. Higher rate of phosphorus produced slightly superior yields during three out of four years.

Table 4. Nitrogen rate and timing and phosphorus rate effects on dry root yield of transplanted *Echinacea angustifolia* grown under irrigation and harvested one, two, three, and four years after establishment:				
Treatment	1998: Year-1	1999: Year-2	2000: Year-3	2001: Year-4
Nitrogen rate				
50 kg N/ha	723	1402	3191	2582
100 kg N/ha	725	1051	3134	3133
Nitrogen timing				
Spring	659	1107	3061	2340
Spring & fall	789	1222	3264	3374
Phosphorus rate				
50 kg P_2O_5/ha	693	1211	2888	2681
100 kg P_2O_5/ha	755	1087	3438	3033
Analyses of Variance				
Source				
Nitrogen rate (N)	ns	ns	ns	ns
Nitrogen Applic. (A)	ns	ns	ns	ns
Phosphorus rate (P)	ns	ns	ns	ns
N x A	ns	ns	ns	ns
N x P	ns	ns	ns	ns
A x P	ns	ns	ns	ns
N x A x P	ns	ns	ns	ns
C.V. (%)	42.4	84.3	57.3	37.4
ns indicate non-significant treatment effects.				

Spacing and Fertilizer Effects Under Dryland and Irrigated Production

Background:
Under commercial scale production, appropriate agronomic practices should be adopted to maximize yields. This includes suitable plant populations and proper fertility management practices. It is likely that the response to fertility levels and plant populations can vary between dryland and irrigated production. This study examines the interactive effects of nitrogen, phosphorus and plant population for transplanted *Echinacea angustifolia* grown under dryland and irrigated conditions.

Treatments:

Plant spacing:	15, 30 cm (within-row).
Nitrogen rate:	0, 75, 150 kg N/ha.
Phosphorus rate:	0, 60 kg P_2O_5/ha.

Row spacing:	60 cm.
Growing conditions:	Dryland and irrigation.
Planting date:	June 1997.
Harvest date:	Fall 1999, 200, 2001

Results

The average root yields were somewhat similar in dryland and under irrigated production at the various harvest stages (Figure 3, Table 5). Root yields were highest at the year-2 harvest and declined sharply in the subsequent years.

Closer in-row spacing (15 cm) produced higher root yields that the wider (30 cm) spacing at all harvest stages under both dryland and irrigated production.

Nitrogen application tended to depress root yields at the various harvest stages under both production conditions.

Phosphorus application had no effect on root yields (Table 5).

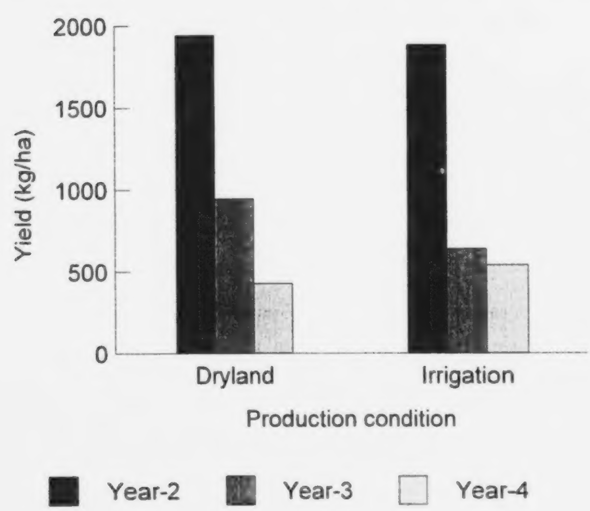


Figure 3. Dry root yields of Echinacea angustifolia grown under dryland and irrigation and harvested two, three, and four years after planting in the plant spacing study.

Table 5. Plant spacing, nitrogen, and phosphorus effects on dry-root yield for transplanted *Echinacea angustifolia* grown under dryland and irrigation and harvested two, three, and four years after establishment

Treatment	Dry root yield (kg/ha)					
	Dryland			Irrigation		
	1999: Year-2	2000: Year-3	2001: Year-4	1999: Year-2	2000; Year-3	2001: Year
Spacing:						
15 cm	2787	1309	451	2451	843	659
30 cm	1196	581	404	1320	435	421
Nitrogen (kg N/ha):						
0	2136	1147	581	1822	782	650
75	1997	1119	418	1946	758	575
150	1842	570	283	1889	377	394
Phosphorus (kg P_2O_5/ha):						
0	2020	908	431	1906	520	516
60	1964	982	424	1865	757	563
Analyses of Variance						
Source						
Spacing (S)	***	***	ns	***	**	**
Nitrogen (N)	ns	**(405)	**(171)	ns	*(345)	ns
Phosphorus (P)	ns	ns	ns	ns	ns	ns
S x N	ns	ns	ns	ns	ns	ns
S x P	ns	ns	**(197)	ns	ns	ns
N x P	ns	*	ns	ns	ns	ns
S x N x P	ns	ns	ns	ns	ns	ns
C.V. (%)	28.2	59.4	55.7	27.8	74.8	57.3

***, **, *, and ns indicate significance at P <0.001, 0.01, 0.05 levels of probability and not significant respectively.
Values within parentheses are LSD estimates at 5.0% level of significance..

Feverfew

Feverfew

Effects of Plant Population and Cutting Stage on Productivity of Feverfew

Background:
Different herb buyers tend to prefer feverfew harvested at different growth stages such as (i) prior to flowering, (ii)during early flowering, or (iii) at full bloom. This study examines the interactive effects plant spacing and harvest stage on herbage yield for transplanted feverfew grown under dryland and irrigated conditions.

Treatments:

Plant spacing:	15, 30 cm (within-row).
Harvest stage:	Pre-flower, 10% flower, 100% flower.
Growing conditions:	Dryland and irrigation
Row spacing:	60 cm.
Study period:	1998, 1999, 2000, 2001, 2002
Cultivar:	'Wild' feverfew (Richter's)

Results

This study was repeated over a five year period in order examine the interactive effects of soil, climate and growing condition on feverfew yield. The average yields were variable under dryland and irrigation during the various years (Figure 4). Irrigated feverfew generally produced higher herb yields than dryland feverfew.

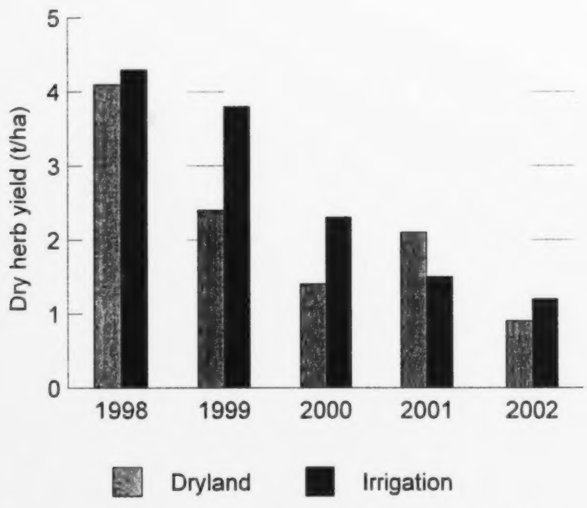


Figure 4. Average yields of dryland and irrigated feverfew in different years.

Under dryland production closer (15 cm) plant spacing generally produced higher herb yields than the wider 30 cm spacing (Table 6). However under irrigation, the wider and narrower spacings generally produced similar herb yields. (Table 7).

Delaying harvesting up to 100% flower generally produced higher yields than earlier harvesting under both dryland (Table 6)and irrigated (Table 7) conditions. Harvesting at pre-flower stage and at 10% flower produced similar herb yields under dryland and under irrigation.

Table 6: Plant spacing effects on dry herbage yields for 'Wild' feverfew grown under dryland

Treatment	Dry herb yield (t/ha)				
	1998	1999	2000	2001	2002
Plant spacing:					
15 cm	4.3	2.5	1.5	2.2	0.9
30 cm	3.9	2.3	1.2	2	0.9
Harvest sage:					
Pre-flower	4	2	1.3	1.8	0.8
10%-flower	3.6	2.4	1.1	1.8	0.8
100%-flower	5.3	2.8	1.5	2.7	0.9
Analyses of variance					
Source:					
Spacing	**(0.5)	ns	**(0.2)	*(0.2)	ns
Harvest stage	***(0.6)	*(0.6)	ns	***(0.2)	ns
Spacing x Harvest stage	ns	ns	ns	ns	ns
C.V.(%)	13.6	21.5	16.9	8.8	24.5

*, **, ***, and ns indicate significance at P<0.05, 0.01, 0.001 levels of probability and not significant respectively.
Values within parentheses indicate significance at 5.0% level of probability.

Table 7: Plant spacing effects on dry herbage yields for 'Wild' feverfew grown under irrigation					
Treatment	Dry herb yield (t/ha)				
	1999	2000	2001	2002	2003
Plant spacing:					
15 cm	4.5	4	2.7	1.5	1.3
30 cm	4	3.5	1.9	1.5	1
Harvest sage:					
Pre-flower	3.8	3.4	2.6	1.4	0.9
10%-flower	4.5	4.3	1.7	1.3	1.1
100%-flower	4.5	3.7	2.8	1.9	1.4
Analyses of variance					
Source:					
Spacing	ns	*	ns	ns	***
Harvest stage	ns	*(0.5)	ns	***(0.3)	***(0.20)
Spacing x Harvest stage	ns	ns	ns	ns	ns
C.V.(%)	27.9	13.2	49.0	21.3	16.6

.*, ***, and ns indicate significance at P<0.05, 0.001 levels of probability and not significant respectively.
Values within parentheses indicate significance at 5.0% level of probability.

Spacing and Fertilizer Effects on Transplanted Feverfew.

Background:
Under commercial scale production, suitable agronomic practices should be adopted to maximize yields. This includes suitable plant populations and proper fertility management practices. It is likely that the response to fertility levels and plant populations can vary between dryland and irrigated production. This study examines the interactive effects of nitrogen, phosphorus and plant population for transplanted feverfew grown under dryland and irrigated conditions.

Treatments:

Plant spacing:	15, 30 cm (within-row).
Nitrogen rate:	0, 50, 150 kg N/ha.
Phosphorus rate:	0, 60 kg P_2O_5/ha.:
Growing conditions:	Dryland and irrigation
Row spacing:	60 cm
Harvest height:	Ground level.

Study period:	1998, 1999, 2000 for dryland 1998, 1999, 2000, and 2001 for irrigation
Cultivar:	'Wild' feverfew (Richter's)

Results

Dry herb yields in response to plant spacing and nitrogen and phosphorus application under dryland and irrigated production are summarized in Table 8 and Table 9 respectively. Dry herb yields were variable in the different years and no consistent trend was observed between the dryland and irrigated production (Figure 5).

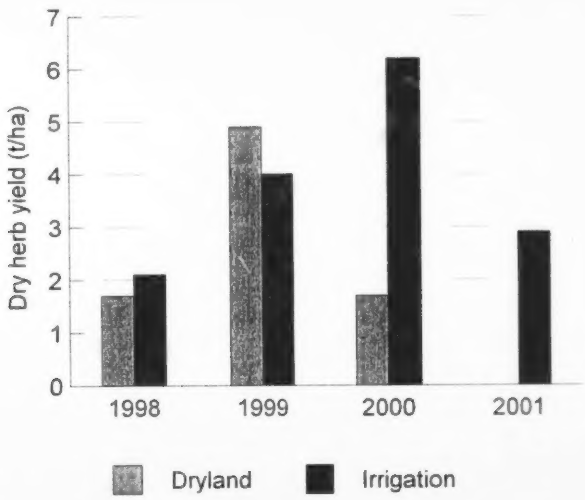


Figure 5. Average yields for dryland and irrigated feverfew.

Under dryland, dry herb yields were generally similar for the two plant spacings (Table 8), Under irrigation closer spacing (15 cm) produced higher herb yields than the wider spacing of 30 cm (Table 9).

Nitrogen application had no effect or depressed yields compared no nitrogen check treatment under both dryland and irrigation (Table 8, and table 9)

Phosphorus fertilizer had no effect on dry herb yields under dryland (Table 8) or under irrigation (Table 9).

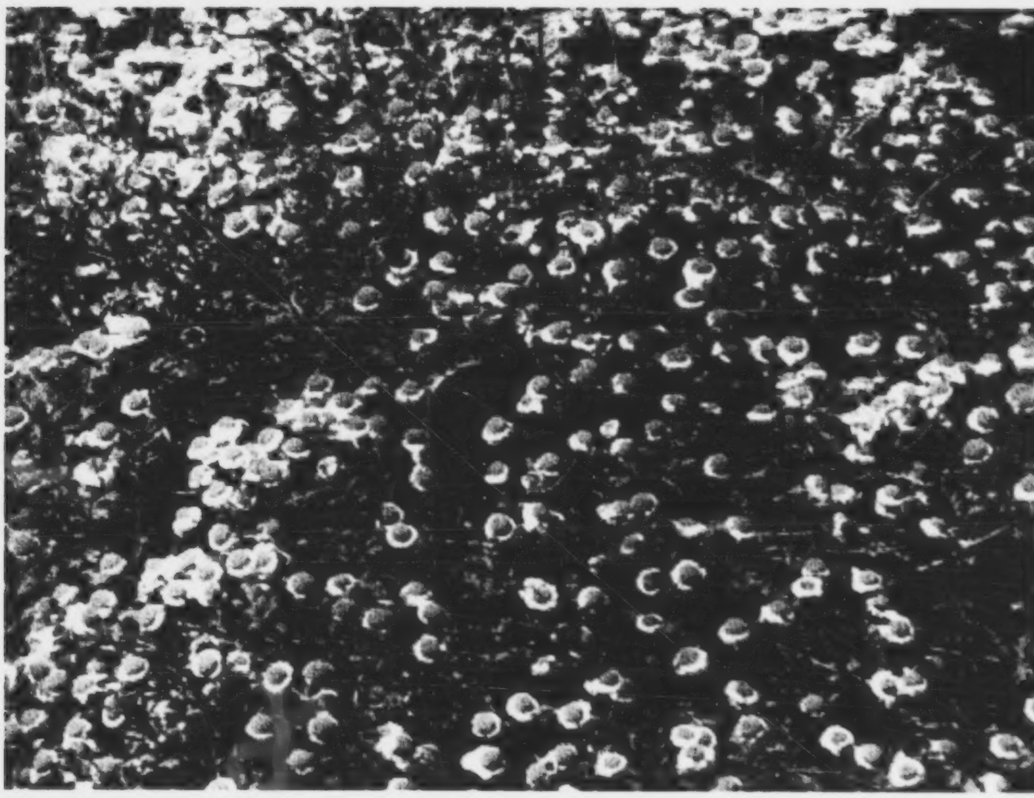
Table 8. Plant spacing and fertility effects on dry herbage yield for feverfew grown under dryland			
Treatment	Dry herb yield (t/ha)		
	1998	1999	2000
Plant spacing:			
15 cm	2.0	5.0	1.7
30 cm	1.4	4.7	1.6
Nitrogen rate:			
0	1.9	4.7	1.8
50 kg N/ha	-	4.9	1.5
100 kg N/ha	1.4	5.0	1.7
Phosphorus rate:			
0	1.6	4.8	1.7
60 kg P_2O_5/ha	1.7	4.9	1.7
ANOVA			
Source			
Spacing (S)	***	ns	ns
Nitrogen (N)	**(0.3)	ns	*(0.3)
Phosphorus (P)	ns	ns	ns
S x N	ns	ns	ns
S x P	ns	ns	ns
N x P	ns	ns	ns
S x N x P	*(0.4)	ns	ns
C.V. (%)	20.1	12.7	15.1

.*, **, ***, and ns indicate significance at P<0.05, 0.01, 0.001 levels of probability and not significant respectively.
Values within parentheses indicate significance at 5.0% level of probability.

Table 9. Plant spacing and fertility effects on dry herbage yield for feverfew grown under irrigation				
Treatment	Dry herb yield (t/ha)			
	1998	1999	2000	2001
Plant spacing:				
15 cm	2.5	4.4	6.6	3.2
30 cm	1.6	3.8	5.8	2.5
Nitrogen rate:				
0	2.2	4.1	6.1	3.1
50 kg N/ha	-	4.1	6.2	3.0
100 kg N/ha	1.9	4.2	6.2	2.5
Phosphorus rate:				
0	2.0	4.2	6.0	2.8
60 kg P_2O_5/ha	2.1	4.0	6.4	2.9
ANOVA				
Source				
Spacing (S)	***	ns	ns	***
Nitrogen (N)	**(0.2)	ns	ns	*(0.5)
Phosphorus (P)	ns	ns	ns	ns
S x N	ns	ns	ns	ns
S x P	ns	ns	ns	ns
N x P	ns	ns	ns	ns
S x N x P	ns	ns	ns	ns
C.V. (%)	13.0	14.9	22.8	20.4

*, **, ***, and ns indicate significance at P<0.05, 0.01, 0.001 levels of probability and not significant respectively.
Values within parentheses indicate significance at 5.0% level of probability.

German Chamomile



German Chamomile

Fertilizer Response for Transplanted German chamomile Under Irrigated Production

Background:
Under commercial scale production, suitable agronomic practices including fertility management should be adopted to maximize yields. It is likely that the response to fertility levels can vary between dryland and irrigated production. This study examines the interactive effects of nitrogen and phosphorus for transplanted German chamomile grown under dryland and irrigated conditions.

Treatments:

Nitrogen rate:	0, 100 kg N/ha.
Phosphorus rate:	0, 60 kg P_2O_5/ha.
Potassium:	0, 50 kg K_2O/ha.
Row spacing:	60 cm.
Plant spacing:	30 cm.
Growing conditions:	1998 - dryland
	1999 - dryland and irrigation
Harvesting:	Approximately 100% bloom

Results

1998:
Application of nitrogen, phosphorus, and potassium, at the rates of 100 kg N, 60 kg P_2O_5, and 50 kg K_2O per hectare respectively did not produce any significant yield responses (Table 10). Additional phosphorus and potassium to tended increase yields slightly, by contrast nitrogen application tended to reduce dry herbage yields.

1999:
German chamomile grown under dryland produced over three-fold yield than irrigated production (Table 11). Under dryland, application of 100 kg/ha nitrogen produced significantly higher total dry herbage yield, while nitrogen had no effect on flower yield (Table 11). Under irrigation, nitrogen application had no effect on flower or total dry herbage yield.

Phosphorus tended to lower flower and total yields compared to the check treatment (Table 11). These differences reached significant levels for stem and total weight under dryland, and for flower weight under irrigation.

Potassium had no effect on plant component yields under dryland (Table 8). Significant phosphorus x potassium interactions were observed for the various plant parts under irrigation (Table 11). It appears that under low potassium (check) levels, adding phosphorus tended to reduce yields of all plant parts (Figure 6). By contrast, under high potassium application, adding phosphorus tended to increase yields.

Table 10. Nitrogen, phosphorus, and potassium mean effects of herbage yield for German chamomile grown under irrigation: 1998	
Treatment	Dry Herbage yield (kg/ha)
Nitrogen (Kg N/ha)	
0	962
100	793
Phosphorus (kg P_2O_5/ha)	
0	874
60	881
Potassium (kg K_2O/ha)	
0	829
50	925
Analysis of Variance	
Source:	
Nitrogen (N)	ns
Phosphorus (P)	ns
Potassium (K)	ns
N x P	ns
N x K	ns
P x K	ns
N x P x K	ns
C.V. (%)	41.6
ns indicate non-significant treatment effects.	

Table 11. Fertility effects on plant part dry yield for German chamomile grown under dryland and irrigation: 1999				
Treatment	Dry herbage yield (kg/ha)			
	Dryland		Irrigation	
	Flower	Total	Flower	Total
Nitrogen (kg N/ha)				
0	854	3128	223	942
100	909	3633	248	855
Phosphorus (kg P_2O_5/ha)				
0	917	3661	257	937
60	846	3101	214	860
Potassium (kg K_2O/ha)				
0	946	3384	252	910
50	818	3379	219	886
ANOVA				
<u>**Source**</u>:				
Nitrogen (N)	ns	*(472)	ns	ns
Phosphorus (P)	ns	*(472)	*(44)	ns
Potassium (K)	ns	ns	ns	ns
N x P	ns	ns	ns	ns
N x K	ns	ns	ns	ns
P x K	ns	ns	**(62)	*(211)
N x P x K	ns	ns	ns	ns
C.V. (%)	26.9	18.9	25.2	22.5

**, * and ns indicate significance at P<0.01, 0.05 levels of probability and not significant respectively.
Values within parentheses are LSD estimates at 5.0% significance.

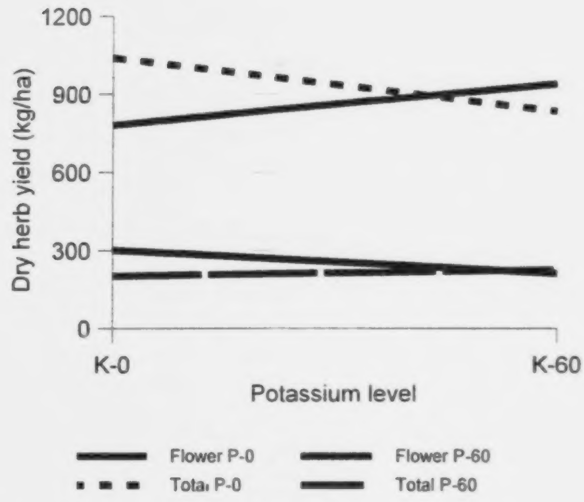


Figure 6. Interactive effect of phosphorus and potassium on dry herb (flower, total) yield.

Effects of P!ant Population and Harvest Method Under Dryland and Irrigated Production

Background:

Under commercial production, German chamomile flowers are harvested by machines. The crop is harvested at different stages as determined by market trends. This study examines the effects of plant population, and the stage/method of harvest on yield and quality.

Treatments:

Within-row spacing:	15, 30 cm.
Harvest height:	Ground level, 10 cm above ground.
Harvest method:	Manual, mechanical.
Growing condition:	1998 - dryland
	1999 - dryland and irrigation
Row spacing:	60 cm
Harvest:	At 100% bloom

Results:

In 1998, only plant population and harvest methods were examined. In 1999, harvest methods and harvest heights were evaluated under two plant spacings. Resulkts of this study are summarized in table 12

1998:

Closer plant spacing and hand harvesting produced significantly higher yields than wider plant spacing and machine harvest respectively (Table 12).

1999:
Under irrigation, closer (15 cm) planting produced significantly higher dry herbage yield than the 30 cm plant spacing (Table 12). Under dryland, higher plant population did not provide any added yield advantage.

Under dryland, harvesting at ground level produced higher yields than harvesting at 10 cm above ground (Table 12). Under irrigation both harvest heights produced similar yields.

Mechanical harvest produced higher yields both under dryland and irrigation (Table 12). It is unclear why mechanical harvesting produced higher yields than manual harvest.

Table 12. Effects of plant population, harvest methods , and harvest height on herbage yield of German chamomile grown under irrigation and dryland: 1998, 1999

Treatment	1998	1999	
	Dryland	Dryland	Irrigation
Plant spacing:			
30 cm	502	2091	1460
15 cm	1129	2165	2096
Harvest method:			
Hand harvesting	1191	1362	1125
Machine harvesting	440	2894	2431
Harvest height:			
10 cm above ground level	-	1987	1783
At ground level	-	2269	1773
Analyses of variance			
Source			
Plant spacing (P)	***	ns	***
Harvesting method (H)	***	**	ns
Harvest height (T)	-	***	***
P x H	ns	ns	ns
P x T	-	ns	*(362)
H x T	-	***(238)	ns
P x H x T	-	ns	ns
C.V. (%)	28.0	10.8	19.6

***, **, * and ns indicate significance at P <0.001, 0.01, 0.05 levels of probability and not significant respectively.
Values within parentheses are LSD estimates at 5.0% significance.

Stinging Nettle

Stinging Nettle

Planting Material Comparison Under Dryland and Irrigation

Background:
Stinging nettle is a hardy perennial with extremely small seeds. Commercially, stinging nettle can be grown using transplants. This study was established in 1997 to examine the effects of plant material on herbage yield.

Treatments:

Production season	Over-wintering	Container type
1. 1997 fall	Heated greenhouse	50-cell plug tray
2. 1997 fall	Straw covered pit	50-cell plug tray
3. 1998 spring	-	50-cell plug tray

Growing conditions: Dryland and irrigation.
Crop establishment: 1998
Harvest: Summer 1998, 1999, 2000, 2001
Row spacing: 61 cm
Plant spacing: 30 cm

Results

Fresh herb yields were relatively low during the first year of production and increased substantially during the following two years (Figure 6). Subsequently, the irrigated crop maintained relatively high yield while there was substantial drop in yield in the dryland crop.

During the first year, the transplants started in the fall of 1997 outyielded transplants started in the spring of the same year (Table 13, and Table 14). In the subsequent years no consistent trends were observed in relation to transplant type and herb yields for both dryland and irrigated crops.

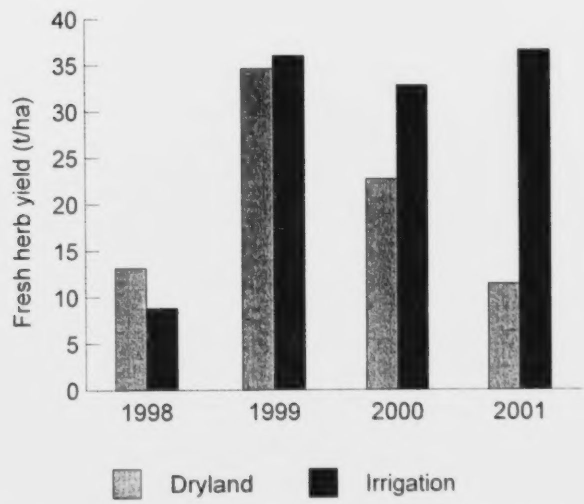


Figure 6. Fresh herb yields of stinging nettle under dryland and irrigated production.

Table 13. Effect of planting material on fresh shoot yield for transplanted stinging nettle grown under dryland and harvested one, two, three, and four years after planting				
Treatment	Fresh shoot yield (t/ha)			
	1998: Year-1	1999: Year-2	2000: Year-3	2001: Year-4
Transplant type:				
Transplants raised during the fall of 1997 and grown in the greenhouse during winter	13.1b	36.6a	16.7a	9.0a
Transplants raised during the fall of 1997 and over-wintered in a straw covered pit	15.9b	33.8a	23.8b	13.0b
Transplants raised in plug trays during the spring of 1998	7.3a	33.4a	27.7b	12.3b
Analyses of Variance				
Source				
Planting material	***	ns	***	**
C.V. (%)	19.5	16.8	58.0	45.8
Within each year, values followed by a different letter are significantly different at 5.0% level of significance.				

Table 14. Effect of planting material on fresh dry shoot yield for transplanted stinging nettle grown under irrigation and harvested one, two, three, and four years after planting				
Treatment	Fresh shoot yield (kg/ha)			
	1998: Year-1	1999: Year-2	2000: Year-3	2001: Year-4
Transplant type:				
Transplants raised during the fall of 1997 and grown in the greenhouse during winter	11.0b	34.8a	40.8b	38.9b
Transplants raised during the fall of 1997 and over-wintered in a straw covered pit	10.0b	36.1a	26.0a	20.0a
Transplants raised in plug trays during the spring of 1998	5.5a	37.0a	31.8a	50.9c
Analyses of Variance				
Source				
Planting material	***	ns	***	***
C.V. (%)	8.3	13.5	19.2	45.8
Within each year, values followed by a different letter are significantly different at 5.0% level of significance.				

Fertility Studies for Transplanted Stinging Nettle Grown Under Dryland and Irrigation

Background:
Stinging nettle root and shoot are used by the industry. It is likely that fertilizer application and production conditions (dryland or irrigation) can influence crop growth and yield. This study examines the effects of nitrogen and phosphorus application on shoot yield.

Treatments:

Nitrogen rate:	50, 100 kg N/ha.
Nitrogen application:	Spring, spring + fall (½ + ½).
Phosphorus rate:	50, 100 kg P_2O_5/ha.
Growing conditions:	Dryland and irrigation
Establishment:	1998
Harvest:	Dryland - 1999, 2000, 2001
	Irrigated - 1998, 1999, 2000, 2001

Results:
Fresh herb yield response to nitrogen rate and timing and phosphorus rate for stinging nettle grown under dryland and under irrigation are summarized in Table 15, and Table 16 respectively. Nitrogen rate and timing or phosphorus application ghad no effect on fresh herb yields.

Table 15. Nitrogen rate and timing and phosphorus rate effects on fresh shoot yield of stinging nettle grown under dryland and harvested one, two, three, and four years after establishment

Treatment	Shoot fresh weight (t/ha)		
	1999: Year-2	2000: Year-3	2001: Year-4
Nitrogen rate			
50 kg N/ha	31.9	21.8	16.7
100 kg N/ha	32.7	21.7	15.3
Nitrogen timing			
Spring	32.6	22.1	16.7
Spring & fall	31.8	21.0	14.7
Phosphorus rate			
50 kg P_2O_5/ha	33.7	20.7	16.8
100 kg P_2O_5/ha	31.0	22.8	15.3
Analyses of Variance			
Source			
Nitrogen rate (N)	ns	ns	ns
Nitrogen timing (T)	ns	ns	ns
Phosphorus rate (P)	ns	ns	ns
N x T	ns	ns	ns
N x P	ns	ns	ns
T x P	ns	ns	ns
N x T x P	ns	ns	ns
C.V. (%)	7.7	28.5	31.0

ns indicates non-significant treatment effects.
Values within parentheses are LSD estimates at 5.0% level of significance.

Table 16. Nitrogen rate and timing and phosphorus rate effects on fresh shoot yield of stinging nettle grown under irrigation and harvested one, two, three, and four years after establishment				
Treatment	Shoot fresh weight (t/ha)			
	1998: Year-1	1999: Year-2	2000: Year-3	2001: Year-4
Nitrogen rate				
50 kg N/ha	5.0	41.8	27.3	28.3
100 kg N/ha	5.8	36.8	26.9	28.4
Nitrogen timing				
Spring	5.8	38.7	27.5	28.6
Spring & fall	5.0	39.5	26.7	28.1
Phosphorus rate				
50 kg P_2O_5/ha	4.7	38.1	27.2	27.9
100 kg P_2O_5/ha	6.1	40.1	26.9	28.8
Analyses of Variance				
Source				
Nitrogen rate (N)	ns	**	ns	ns
Nitrogen timing (T)	ns	ns	ns	ns
Phosphorus rate (P)	**	ns	ns	ns
N x T	ns	ns	ns	ns
N x P	ns	ns	ns	ns
T x P	ns	ns	ns	ns
N x T x P	ns	ns	ns	ns
C.V. (%)	20.6	11.0	16.4	29.6

** and ns indicate significance at P<0.01 level of probability and not significant respectively. Values within parentheses are LSD estimates at 5.0% level of significance.

Plant Spacing and Cutting Height Effects for Transplanted Stinging Nettle Grown Under Dryland and Irrigation

Background:
Stinging nettle leaf is one of the plant parts used for herbal remedies. Plant spacing and cutting height can affect herbage yield and quality. Moisture status during the growing season can also influence productivity and level of marker compounds. This study examines the effects of plant population and cutting height on stinging nettle grown under dryland and irrigation.

Treatments:

Plant spacing:	15, 30 cm.
Cutting height:	Ground level, 10 cm, 15 cm above ground.
Growing conditions:	Dryland and irrigation

Row spacing:	60 cm
Establishment:	1998
Harvest:	1998, 1999, 2000, 2001

Results

As observed in the planting material study, fresh herb yields were relatively low during the first year of production and increased substantially during the following two years (Figure 7). Subsequently, the irrigated crop maintained relatively high yield while there was substantial drop in yield in the dryland crop.

Plant spacing had no effect on herb yield under both growing conditions (Table 17, Table 18).

During the establishment year (1998) under dryland and irrigated production, harvesting the crop at ground level produced higher herb yields than harvesting at 10 cm or 15 cm above ground level. In the following three years, cutting height had no effect on herb yields under both dryland and irrigated production.

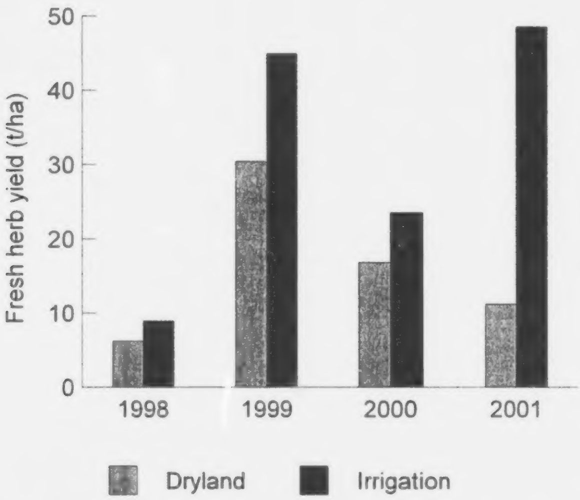


Figure 7. Fresh herb yields for stinging nettle under dryland and irrigated production.

Table 17. Plant spacing and cutting nheigh effects on fresh shoot yield of stinging nettle grown under dryland and harvested one, two, three, and four years after establishment				
Treatment	Shoot fresh weight (t/ha)			
	1998: Year-1	1999: Year-2	2000: Year-3	2001: Year-4
Plant spacing:				
15 cm	6.3	31.5	16.5	11.7
30 cm	6.0	29.9	17.0	10.6
Cutting height::				
Ground level	8.4	28.7	17.5	10.9
10 cm above ground	5.6	32.0	16.4	11.3
15 cm above ground	4.3	31.3	16.2	11.3
Analyses of Variance				
Source				
Spacing (S)	ns	ns	ns	ns
Cutting height (H)	***(1.5)	ns	ns	ns
S x H	Ns	ns	ns	ns
C.V. (%)	23.3	14.9	29.2	38.3

*** and ns indicate significance at P<0.001 level of probability and not significant respectively. Value within parenthesis is LSD estimate at 5.0% level of significance.

Table 18. Plant spacing and cutting nheigh effects on fresh shoot yield of stinging nettle grown under irrigation and harvested one, two, three, and four years after establishment				
Treatment	Shoot fresh weight (t/ha)			
	1998: Year-1	1999: Year-2	2000: Year-3	2001: Year-4
Plant spacing:				
15 cm	9.7	45.2	22.8	46.8
30 cm	8.1	44.6	24.1	50.1
Cutting height::				
Ground level	12.7	42.1	24.1	50.7
10 cm above ground	7.5	44.2	23.3	46.1
15 cm above ground	6.4	48.3	23.0	48.5
Analyses of Variance				
Source				
Spacing (S)	ns	ns	ns	ns
Cutting height (H)	***(1.8)	ns	ns	ns
S x H	ns	ns	ns	ns
C.V. (%)	19.5	17.4	33.5	24.2

***, ** and ns indicate significance at P <0.001, 0.01 levels of probability and not significant respectively.
Value within parenthesis is LSD estimate at 5.0% level of significance.